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# Swine Lagoon Effluent Applied to Coastal Bermudagrass

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# SWINE LAGOON EFFLUENT APPLIED TO COASTAL BERMUDAGRASS

by

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The utilization potential and the environmental effects of applying swine lagoon effluent to Coastal bermudagrass were evaluated for six years. Lagoon effluent was applied to 9m x 9m plots by weekly sprinkler irrigation during the growing season. Forage yield and quality, soil nutrient levels and water quality and quantity of runoff and subsurface lateral flow were evaluated. An intake trial with ewes was also conducted to determine animal acceptance of hay from lagoon-irrigated treatments.

The results indicated that swine lagoon effluent can be an excellent source of nutrients for Coastal bermudagrass but water quality considerations, nitrate levels in forage, and long-term soil effects must be evaluated when determining acceptable maximum application rates, which is important when land area for application is limiting.

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# FOREWORD

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This project was initiated to evaluate the effects of applying swine lagoon effluent to Coastal bermudagrass. Forage yield and quality, soil nutrient levels and water quality and quantity of runoff and subsurface lateral flow were evaluated. Livestock intake trials were conducted to determine animal acceptance of hay from lagoon-irrigated treatments. This information is useful in determining optimal practices which will lead to the development of Best Management Practices (BMPs).

Clinton W. Hall

Clinton W. Hall, Director
Robert S. Kerr Environmental
Research Laboratory

# ABSTRACT

The utilization potential and the environmental effects of applying swine lagoon effluent to Coastal bermudagrass were evaluated for six years. Lagoon effluent was applied to 9 m x 9 m plots by weekly sprinkler irrigations during the growing season. A randomized block design with three application rates based on nitrogen (N) (about 335, 670 and 1,340 kg N/ha/yr) was utilized. The high-rate treatment resulted in applications of N, phosphorus (P) and potassium (K) at about five, thirteen, and eleven times, respectively, the normally recommended fertilizer application rates for high yields of hay.

Forage yield and quality, soil nutrient levels and water quality and quantity of runoff and subsurface lateral flow were evaluated. An intake trial with ewes was also conducted to determine animal acceptance of hay from lagoon-irrigated treatments.

The results indicated that swine lagoon effluent can be an excellent source of nutrients for Coastal bermudagrass but water quality considerations, nitrate levels in the forage, and long-term soil effects must be evaluated when determining acceptable maximum application rates, which is important when land area for application is limiting.

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## LIST OF ABBREVIATIONS AND SYMBOLS

### ABBREVIATIONS

AET -- actual evapotranspiration
Al -- aluminum
Ca -- calcium
CEC -- cation exchange capacity
$Cl^-$ -- chloride
COD -- chemical oxygen demand
Cu -- copper
ET -- evapotranspiration
Fe -- iron
HCl -- hydrochloric acid
$HNO_3$ -- nitric acid
$H_2SO_4$ -- sulfuric acid
IVDMD -- in vitro dry matter disappearance
k -- hydraulic conductivity
K -- potassium
$K_2O$ -- potash
Mg -- magnesium
Mn -- manganese
$\underline{N}$ -- normality
N -- nitrogen (total nitrogen, including nitrate nitrogen unless otherwise indicated)
Na -- sodium
$NH_3$-N -- ammonia nitrogen (includes ammonia nitrogen and ammonium ($NH_4^+$) nitrogen)
$NO_3$-N -- nitrate ($NO_3^-$) nitrogen
O-$PO_4$-P -- orthophosphate phosphorus
P -- total phosphorus
PET -- potential evapotranspiration
$P_2O_5$ -- phosphorus (V) oxide, often referred to as phosphate
Rep. -- replication
S -- sulfur
TKN -- total Kjeldahl nitrogen (organic nitrogen plus ammonia nitrogen)
TOC -- total organic carbon
UV -- ultra violet spectrum
Zn -- zinc

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# SECTION 1

# INTRODUCTION

Swine production systems which utilize anaerobic lagoons usually require a land receiver system for lagoon effluent to avoid lagoon overflow. The ability of a soil-plant receiver system to utilize applied lagoon effluent depends primarily upon the crop and the soil chemical and physical properties. Climate, lagoon effluent application rate, and effluent composition also affect the utilization.

The design of the lagoon and the soil-plant receiver system depends largely on whether the producer's main objective is (1) manure treatment and disposal or (2) utilization of manure nutrients for useful crops. If the producer is limited by land, he would desire maximum lagoon treatment and apply effluent to the soil-plant receiver system at maximum rates which could be sustained without causing toxicity to plants, failure of soil structure, or excessive degradation of ground water and rainfall runoff. Also, if the plants are to be fed to animals, the mineral and metal composition must not reach toxic levels. On the other hand, if the producer is not land-limited and he desires to utilize the lagoon effluent for crop irrigation and fertilization, he may design the lagoon to minimize nutrient losses and apply the effluent at rates based on efficient crop utilization of nutrients. Then he must decide whether to base application rate on N, P or another element. Typically, if N is the base element, P and K are applied in excess of plant utilization. However, if P is the base element, then additional N must be applied with commercial fertilizer. Thus, depending upon the producer's objectives and the land restrictions, a wide range of nutrient loading rates may be found in practice. A major question arises as to whether the maximum rate is limited by detrimental effects to crop, or soil, or by water quality of ground water and runoff.

One crop which is receptive to irrigation of swine lagoon effluent in the Southeast is Coastal bermudagrass (*Cynodon dactylon* L. Pers). It is a deep-rooted, long-lived perennial which has a hot weather growth period and requires a well-drained soil. It also can remove relatively large amounts of N which is often used as the base element for determining effluent application rates. Coastal bermudagrass on a Norfolk sandy loam soil was utilized in this study as the plant-soil receiver system. Lagoon effluent was applied during the crop growing season to replicated plots at three N levels ranging from a fertilization rate normally recommended for high yields to a rate five times higher.

Results are presented for six years of monitoring irrigation applications, crop yield and composition, soil cores, and runoff. Also included is a 20-month period of monitoring subsurface flow on three plots. Because most studies of this type have covered only one to three years, this study demonstrates long-term effects which may not be evident in short-term studies, especially in regard to soil accumulation and water transport of possible pollutants.

# SECTION 2

# CONCLUSIONS

Weekly irrigation of swine lagoon effluent to Coastal bermudagrass during the growing season resulted in excellent crop response. Yields increased with increased application rates, but there was little advantage in dry matter production from applying N above the medium rate (670 kg N/ha/yr). Applying N, P, and K up to four, thirteen, and eleven times, respectively, the normal recommended rates for high hay yields under non-irrigated conditions did not result in any significant problems with forage quality or soil physical structure for the six years of the study, except that nitrate nitrogen ($NO_3$-N) levels in forage from the highest-rate treatment may be near a hazardous level for animal intake. Soil sampling results indicated that continued application at the highest two rates could cause some nutrient imbalances due to high P accumulation (e.g., reduced iron (Fe) uptake), and periodic liming would probably be needed to correct for calcium (Ca) and magnesium (Mg) losses from the topsoil and the decreased pH. The Ca and Mg deficiencies may occur even though large amounts of these and other minor elements are applied with the lagoon effluent.

Transport of nutrients in surface runoff was relatively low because of the sandy topsoil and low slope of the plots. Greater transport generally occurred in subsurface drainage for this layered soil. The high nutrient concentrations in surface and subsurface flow and high transport of $NO_3$-N in subsurface flow from the highest two treatments would probably be unacceptable in most situations as related to water quality, and thus environmental concerns with water pollution will likely govern the application rate for disposal of lagoon effluent. Keeping application rates near the low-rate treatment (near normal crop fertilization)would utilize a greater percentage of the nutrients and be more acceptable environmentally.

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# SECTION 3

## RECOMMENDATIONS

After six years of applying swine lagoon effluent to Coastal bermudagrass, no significant detrimental soil effects or nutrient imbalances in plant uptake were evident even when applying nutrients at several times the normal fertilization rates. However, some trends indicated potential agronomic problems if high-rate applications continued, and the water quality of surface runoff and drainage from the plots receiving high-rate applications was of environmental concern. Some of these trends were not evident after the first two to three years, which is the normal length of studies of this type. Thus, researchers and research funding agencies should set priorities to allow for some long-term studies of this type. Some recommended research areas are:

1. Studies of ten years or longer duration should be conducted to determine long-term effects of continuing excess applications of nutrients with livestock and poultry manures and lagoon effluent. Various plant-soil receiver systems should be studied because soil changes, plant nutrient imbalances, and water quality effects will vary with soil type, plant type and hydrologic conditions. Thus, the nutrient upon which application rates should be based can vary from system to system.

2. The application losses of N by $NH_3$-N volatilization and the soil reduction of $NO_3$-N by denitrification needs further study, particularly with lagoon effluent irrigation systems. $NH_3$-N losses and mineralization rate of organic nitrogen applied needs further study in order to compare availability rate in these systems with that in agronomic systems using commercial inorganic fertilizer. Also, it is difficult to determine how much of the N in the soil is denitrified and how much is transported as $NO_3$-N by lateral soil-water flow and deep seepage and thus is a potential water quality problem.

3. Long-term studies of this type should be conducted with other crops, other soils, and other management strategies such as year-round irrigation, less frequent irrigation, and basing lagoon effluent application rate on P or K and adding supplemental N in commercial fertilizer. Economics of alternatives should be evaluated.

4. Actual field-size systems should be studied, including evaluation of impact on water quality of ground water and nearby streams.

# SECTION 4

# EXPERIMENTAL PROCEDURES

## INTRODUCTION

The application of plant nutrients by irrigation of swine lagoon effluent and the fate of those nutrients through crop uptake, soil accumulation, rainfall runoff transport, and leaching were evaluated using randomized block statistical design for three application levels and standard-type procedures for collection and analyses of forage, soil cores and rainfall runoff. The formal study was for six years. Forage yield data was collected during the seventh year to clarify plant persistence.

## SITE DESCRIPTION AND EXPERIMENTAL DESIGN

The experiment was conducted at the North Carolina State University Central Crops Research Station about 30 km east of Raleigh. The total system included two swine buildings with a gutter-flush system for manure transport to a lagoon and an automated irrigation sprinkler system for irrigating the lagoon effluent onto the Coastal bermudagrass plots (Figure 1). Further description of the swine facilities and lagoons were reported by Humenik and Overcash (1976).

Prior to this study, the application site had been used for forage crops. The soil type is a Norfolk sandy loam (Typic Paleudult; fine-loamy siliceous, thermic) which is typical of much of the Coastal Plains region of North Carolina and the Southeast. In May 1972, certified Coastal bermudagrass was established by sprigging after fumigation with methyl bromide. Stand establishment and maintenance are discussed later.

Three replications of three effluent loading rates were utilized in a randomized block design (Figure 1). Plots were 9.2 x 9.2 m and had a subplot 2.3 x 4.6 m used for water runoff studies. Replications one and two were adjacent and characterized by a loamy sand A horizon of 55 to 70 cm deep. Replication three was further downslope and had a loamy sand A horizon depth of 35 to 50 cm. The B horizon was sandy clay loam and had much lower permeability than the A horizon. Hydrologically, this resulted in a well-drained or permeable layer (hydraulic conductivity k = 6-9 cm/hr) on top of a tight or less permeable zone (k = 0.8-2 cm/hr) (Lutz, 1970). Adjacent to replication three, but sufficiently removed to insure no drift from irrigation, were located four 1.6 by 6.5 m areas to serve as reference plots. An additional four reference plots to conform to the shape of runoff subplots contained within the irrigated plots were added in October 1975. To prevent interflow from above the study site and between the upslope and downslope

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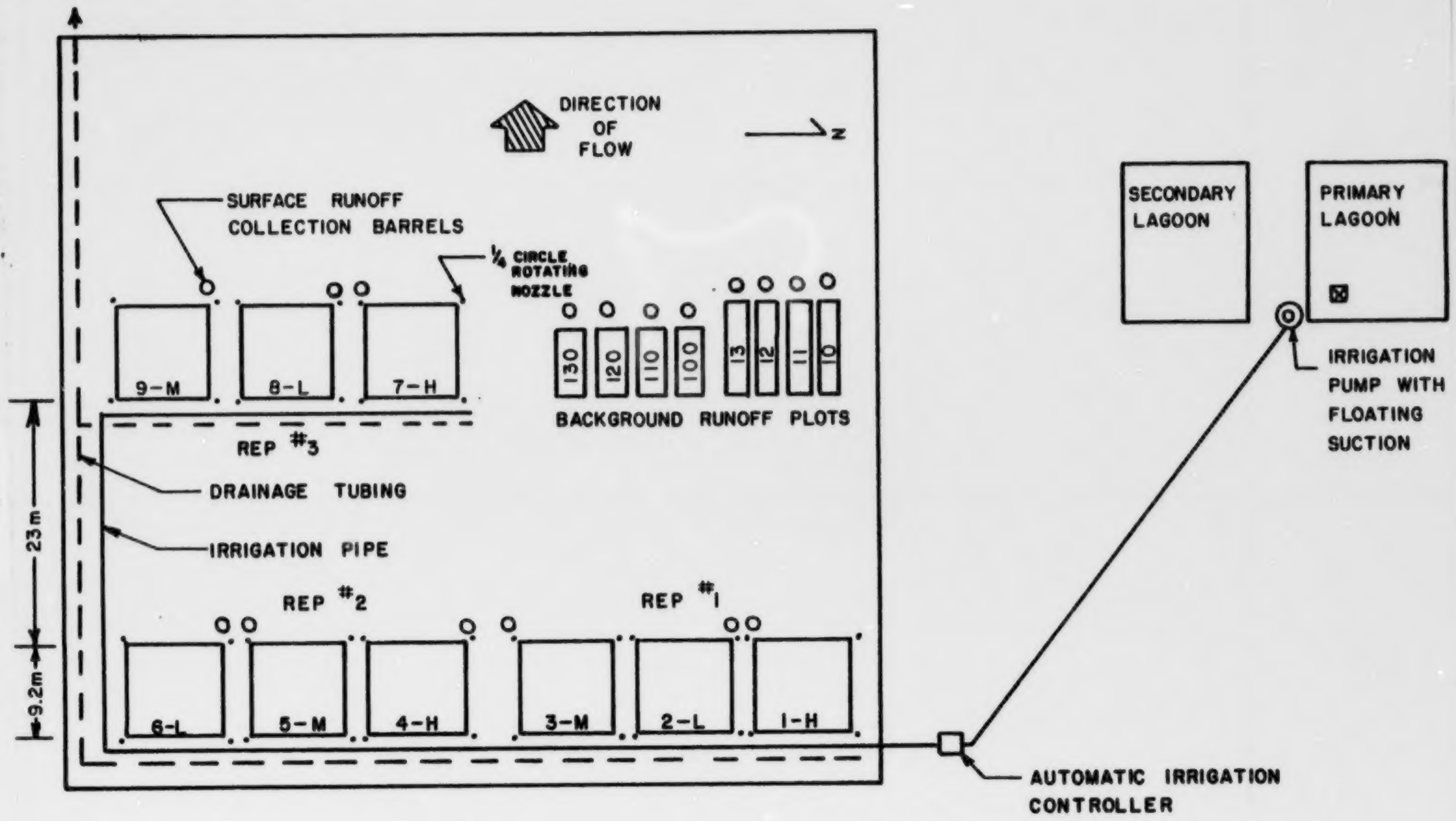
DIRECTION OF FLOW
N
SURFACE RUNOFF COLLECTION BARRELS
¼ CIRCLE ROTATING NOZZLE
9-M
8-L
7-H
130
120
110
100
13
12
11
10
BACKGROUND RUNOFF PLOTS
SECONDARY LAGOON
PRIMARY LAGOON
IRRIGATION PUMP WITH FLOATING SUCTION
REP #3
DRAINAGE TUBING
IRRIGATION PIPE
REP #2
REP #1
6-L
5-M
4-H
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2-L
1-H
23m
9.2m
AUTOMATIC IRRIGATION CONTROLLER

Figure 1. Schematic diagram of research site.

irrigated plots, interceptor drain lines were installed at the 1- to 1.5-m depth at the locations shown in Figure 1.

Galvanized metal flashing was installed to border the runoff subplot and all but the downslope side of the irrigated plots (Figure 2). The 23-cm wide flashing was buried 13 cm giving a 10-cm above-ground isolation barrier for surface runoff. In June 1977, replication two was changed to collect surface runoff from the entire area of the irrigated plots and a subsurface drainage tube was also installed to collect subsurface water. This and other plot modifications for runoff collection are discussed later.

Lagoon effluent was normally irrigated once weekly at night during the growing season (April through September).

To achieve uniform effluent distribution, the irrigation nozzles were located at the corner of each plot and were operated as one-quarter turn sprinklers having a radius equal to about 9.8 m (Figure 2). The wetted area extended outside the 9.2 x 9.2 m area by about 0.6 m to assure total plot coverage. The various application rates were achieved by varying the irrigation time.

Irrigation equipment included a 3.8 cm diameter main header from the lagoon, a 2 horsepower centrifugal pump (Stayrite DHHG), laterals to each plot, electric control valves to regulate flow to sprinkler nozzles, and a time controller (Rainbird RC-12 controller). The sprinklers were operated two at a time to reduce application rate and irrigation runoff.

## FORAGE EXPERIMENTAL PROCEDURES

The establishment and maintenance of forage is important to the continuing operation of a land application system. The forage water tolerance and capability for utilizing various nutrients must be considered when establishing application rates of effluent and its nutrients.

### Stand Establishment

After fumigation with methyl bromide and sprigging of Coastal bermudagrass in May 1972, the area was irrigated as needed through the summer of 1972. After the appearance of new growth, low rates of nitrogen (45 kg/ha) were applied as ammonium nitrate at 30-day intervals during 1972 and the area was clipped frequently to encourage growth. By fall, the total area was covered and 10 to 15 cm of bermudagrass residue was left during the winter as a guard against winter injury.

### Nutrient Application

Seasonal rates of 335, 670, and 1340 kg/ha of N were selected and used as the bases for effluent application. These rates required seasonal application amounts of approximately 14, 28, and 52 cm, respectively, of effluent but varied depending on effluent nitrogen concentrations and uniformity of sprinkler application. A summary of nitrogen application objectives are summarized in Table 1.

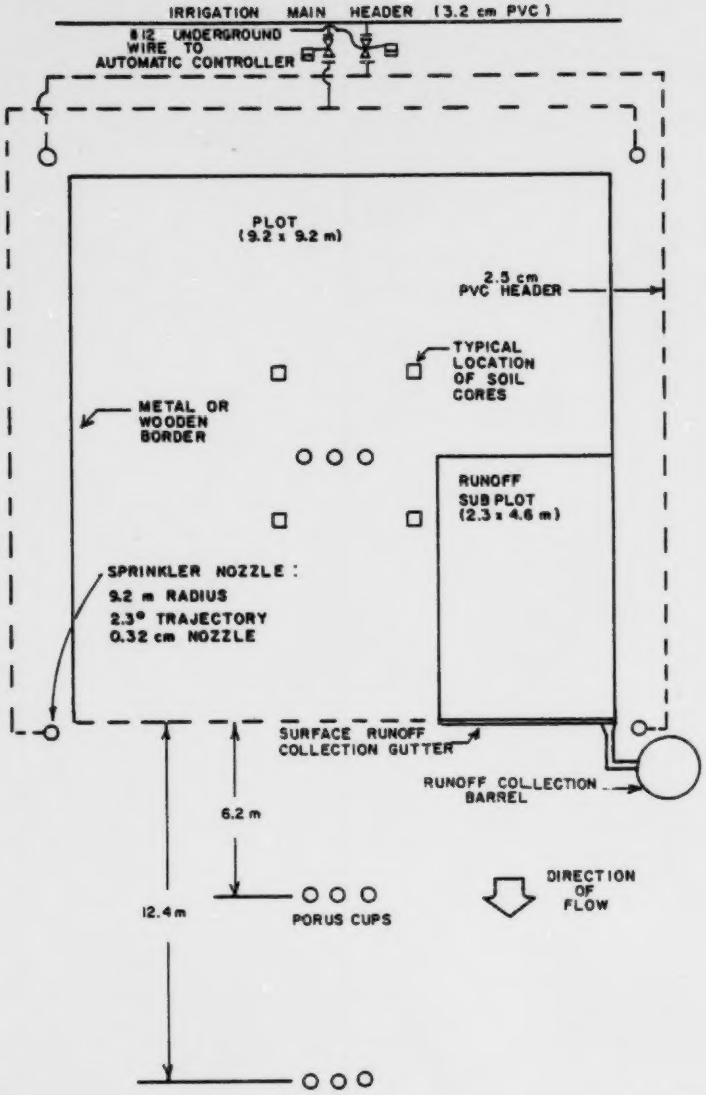
IRRIGATION MAIN HEADER (3.2 cm PVC)
#12 UNDERGROUND WIRE TO AUTOMATIC CONTROLLER
PLOT (9.2 x 9.2 m)
2.5 cm PVC HEADER
TYPICAL LOCATION OF SOIL CORES
METAL OR WOODEN BORDER
RUNOFF SUB PLOT (2.3 x 4.6 m)
SPRINKLER NOZZLE :
9.2 m RADIUS
2.3° TRAJECTORY
0.32 cm NOZZLE
SURFACE RUNOFF COLLECTION GUTTER
RUNOFF COLLECTION BARREL
6.2 m
12.4 m
PORUS CUPS
DIRECTION OF FLOW

Figure 2. Schematic of experimental plot for land application of swine lagoon effluent.

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## TABLE 1. MANAGEMENT FOR COASTAL BERMUDAGRASS PLOTS

| Plots | | | Nitrogen application | | | Grass management | | |
|---|---|---|---|---|---|---|---|---|
| Number of plots | Code No. | Size | Form | Approximate rate, kg/ha/yr | Approximate frequency | Simulated condition | Height at cutting, cm | Height of stubble, cm |
| 3 | 2,6,8 | 9.2 m x 9.2 m | lagoon effluent | 335 | once/week, May-Sept. | hay | 30-35 | 6 |
| 3 | 3,5,9 | 9.2 m x 9.2 m | lagoon effluent | 670 | once/week, May-Sept. | hay | 30-35 | 6 |
| 3 | 1,4,7 | 9.2 m x 9.2 m | lagoon effluent | 1340 | once/week, May-Sept. | hay | 30-35 | 6 |
| 2 | 10,12 | 1.6 m x 6.5 m | ammonium nitrate | 200 (67 kg/ha/application) | 4/20, 6/20, 7/20 | grazing | 15-20 | 4 |
| 2 | 100,120 | 2.3 m x 4.6 m | | | | | | |
| 2 | 11,13 | 1.6 m x 6.5 m | ammonium nitrate | 335 (84 kg/ha/application) | 4/20, 6/1, 7/1, 8/1 | hay | 25-30 | 6 |
| 2 | 110,130 | 2.3 m x 4.6 m | | | | | | |

Samples for determining nutrient applications were taken from cups which collected irrigation lagoon effluent near the surface of the Coastal bermudagrass plots. Samples of lagoon effluent were also taken weekly to compare to the irrigation samples. Volume of applied effluent was determined in 1973-1975 with a water meter and the distribution to plots was assumed to be the desired ratio of 1:2:4 for the three treatments. The water meter sometimes malfunctioned, and the cup volumes indicated that variation in sprinkler output due to clogging or other reasons caused uneven distribution to the plots. Thus, four cups were put on every plot during 1976-1979 and the cup volumes were used for estimating volume of effluent to each irrigated plot.

Loading rates were calculated in 1973 and 1974 by multiplying volume of effluent pumped (as indicated by a water meter) by mean concentration obtained from liquid samples collected at each irrigation in 400 ml cups placed in each plot. Two collectors were placed in each plot and then composited for analyses. The quantities of each constituent applied for each irrigation event were summed for the season, assuming the correct distribution ratio (1:2:4) to plots. In 1975, loading rates were calculated by multiplying volume pumped each month by a monthly mean concentration for liquid collected in cups and summing over months assuming the correct distribution ratio to plots. Monthly mean concentrations were used because of the difficulty of filling in missing data. Missing data occurred mainly because samples were not analyzed when rainfall was mixed in. Monthly mean concentrations were calculated using one mean concentration for each irrigation event that had data and no rainfall mixed in, using four cups per plot and two plots chosen randomly. In 1976 through 1979, the volume applied was calculated for each event for each plot using four collector cups per plot, placing one in the center of each quadrant. Monthly mean concentrations were calculated using one mean concentration for each irrigation event that had data and no rainfall mixed in. Normally, four plots were chosen and four cups were composited for each of the four plots resulting in analyses on four samples per irrigation event, except only one sample was used for minerals and metals analyses. Monthly application rates were calculated for each plot using the calculated volume for each plot and the monthly mean concentrations. Comparison of pumped volume and cup-collection volumes are presented in Appendix A. Also, the effect of inserting funnels in the cups to reduce evaporation and ammonia volitilization is discussed there.

Lagoon liquid and irrigated effluent were analyzed for TKN, $NH_3$-N, P, K, Ca, Mg, Na, $Cl^-$, Cu, Zn, COD, total organic carbon (TOC), and during some periods for pH, Fe, Mn, and orthophosphate phosphorus (O-$PO_4$-P). Methods of analyses are given in another section.

The four reference plots were randomized into two replications each of a hay or a simulated grazing treatment (Table 1). These plots received no supplemental water and were topdressed in February with 50 and 100 kg/ha of $P_2O_5$ (phosphate) and $K_2O$ (potash), respectively, for the simulated grazing treatment and 84 and 168 kg/ha for the hay treatment. Ammonium nitrate was applied to the simulated grazing treatment at 67 kg/ha normally in April, June and July totalling 201 kg/ha for the summer. The hay treatment received 84 kg/ha usually in April, June, July and August totalling 336 kg/ha for the summer. An additional two replications of these two treatments were added in 1976 and managed similarly. Actual dates for fertilizer applications for 1975-1978 are given in Table 2.

## Stand Maintenance

In early April, stands were clipped to a 2.5 cm stubble to remove the previous season's residue. Broadleafed weeds were controlled in the spring, if needed, using either 2.8 kg/ha of 2,4,-D or Banvil D. Annual grasses, if present, were controlled in the summer with 11.2 kg/ha of monosodium arsenate. In instances where stands received winter injury, the areas were re-sprigged and treated as needed with these chemicals. The application of 14.2 kg/ha of Sevin was used on occasions where excessive insect activity was noted.

All plots were permitted to accumulate a minimum of 10 cm of cover prior to frost. In many instances, accumulations were greater. Following the dormancy of bermudagrass, a harvest strip was generally taken to obtain a yield estimate of the residue forages and its composition was determined and used in mass balance determinations. The total plot was never clipped to a short stubble after frost and left exposed.

Stands were scored for plant density when stand thinning was evident. Excellent stands were scored 1 and thin stands (1 sprig every 0.6 to 1.2 m) were scored 10.

## Effluent Residue on Forage Surface

A series of short-term experiments were conducted to determine the extent that effluent residue remained on forage surfaces at the time of harvest. Both the composition of the residue and the concentration of its constituents were of interest.

Whole plant samples were cut to a 6 cm stubble, placed in a plastic bag and returned to the laboratory. Specific procedures for each experiment are detailed below.

### Experiment 1 --

This study determined the influence of sample size and extraction time on removal of N and minerals from whole plant samples.

A bulk fresh, whole-plant sample was used in a 3 x 3 factorial experiment with three replications. Variables were 10, 20 and 30 g of plant material and each washed for 5, 10 and 15 min. for each 500 ml of solution. The whole-plant samples were placed in a 2,000 ml Erlenmeyer flask to which 500 ml of water containing a surfactant was added, stoppered and placed on a wrist-action shaker for the designated time. Each sample was further extracted with two additional 500 ml aliquots resulting in a total wash of 1,500 ml. The final 500 ml washing did not contain the surfactant. The 1,500 ml wash was steam evaporated to 100 ml and freeze-dried to dryness. The residue was weighed and brought back in water to volume. Total N was determined by routine micro-Kjeldahl on a 10 ml aliquot. This permitted

## TABLE 2. DATES OF FERTILIZER APPLICATIONS FOR REFERENCE PLOTS

| Year | Simulated pasture[§,*] (Plots 10, 12, 100, 120) |  | Simulated hay[§,+] (Plots 11, 13, 110, 130) |  |
|---|---|---|---|---|
|  | P & K | N | P & K | N |
| 1975 | 4/28 | 4/28 | 4/28 | 4/28 |
|  |  | 6/30 |  | 6/6 |
|  |  | 7/22 |  | 7/22 |
|  |  |  |  | 8/21 |
| 1976 | 2/19 | 4/21 | 2/19 | 4/21 |
|  |  | 6/11 |  | 6/24 |
|  |  | 7/9 |  | 8/6 |
|  |  |  |  | 10/5 |
| 1977 | 2/17 | 4/18 | 2/17 | 4/18 |
|  |  | 6/16 |  | 6/16 |
|  |  | 7/18 |  | 8/17 |
|  |  |  |  | 9/15 |
| 1978 | 2/21 | 4/17 | 2/21 | 4/17 |
|  |  | 6/9 |  | 6/9 |
|  |  | 7/6 |  | 7/6 |
|  |  |  |  | 7/26 |

[§] Plots 100-130 were not added until October 1975. Plots 10-13 were not maintained after 1978.

[*] For simulated pasture plots, applications were 22 and 84 kg/ha for P and K, respectively, and 67 kg/ha of N for each of the three N applications (N total of 201 kg/ha/yr).

[+] For simulated hay plots, applications were 37 and 140 kg/ha for P and K, respectively, and 84 kg/ha of N for each of the four N applications (N total of 336 kg/ha/yr). Applications of N were made after each of first three harvests.

the determination of the N concentrations in the wash and mg of N in the residue. The remaining aliquot was used for the determination (ppm) of Na, K, $Cl^-$, Ca, Fe, Mg, Mn, Cu and Zn.

Experiment 2 --

This study examined the influence of washing methods on the removal of N and minerals from whole plant samples. Fresh, whole plant samples were used in a 2 x 2 x 3 factorial experiment with three replications. The variables consisted of two bulk samples, one which had been irrigated previously with lagoon effluent and the other topdressed with ammonium nitrate. Fresh plant subsamples of 30 g each were washed either by water or by water plus a surfactant. Plant tissue within each solution was washed by three methods. These were 1) initially agitated and left standing, 2) placed in an open enamel pan and scrubbed gently with a soft bristled brush, or 3) placed in a 2,000 ml Erlenmeyer flask and placed on a shaker.

Each sample was initially washed in 500 ml for 10 minutes. This was followed by two subsequent 500 ml washings. The resulting 1,500 ml were processed as noted in Experiment 1. In this study the washed plant residue was freeze-dried, ground and analyzed for total nitrogen.

Experiment 3 --

Fresh whole plant samples harvested at similar times from each plot in June, July, August and September in 1973 were washed to obtain an estimate of the surface residue among treatments. Based on the results of Experiments 1 and 2, 20 g of fresh plant material was placed in a 2,000 ml Erlenmeyer and washed in three consecutive 500 ml washings for 10 min. each on a platform shaker. The 1,500 ml of washings were handled as described in Experiment 1.

Experiment 4 --

Fresh whole plant samples harvested at similar times from each plot in June, July and August in 1975 were washed as described in Experiment 3. In this study elemental concentrations of the original, unwashed sample, the residual sample after washing and the subsequent wash were determined and compared.

## Yield and Quality Determinations

Forage in the irrigated plots were considered ready for harvest (hay stage) when it attained 30-36 cm of growth. Because N and water were variables, forage for the various treatments grew at different rates. Consequently, treatments were generally harvested independently. Because of weather patterns, harvests were sometimes delayed until forage reached 53 cm of growth. Two swaths (0.5 x 8.3 m each) were harvested at random from the 9 x 9 m plots with a sickle mower to a stubble height of 6.3 cm. The forage from both swaths were combined and weighed green and subsampled for dry matter determinations and laboratory analyses. The dry land treatments managed as hay were considered ready for harvest when forage exceeded 25.4-35.6 cm of growth. The simulated grazing treatment was to be harvested when growth exceeded 15.2 cm. One strip (0.5 x 6.5 m) was harvested from each plot. Forage was cut to a 3.8 cm stubble and sampled as indicated above. All subsamples were dried in a forced air oven, ground through a Wiley mill with a screen with 1 mm openings and stored in a plastic bag until analyzed in the laboratory.

Forage quality was determined using the in vitro bioassay. Analyses were for N, P, K, Na, Ca, Mg, Cu, Mn, Zn, Fe, $Cl^-$, $NO_3$-N and $NH_3$-N.

## Sheep Intake Trial

Combining the forage remaining from the three replications of each of the three treatments following sampling for dry matter determinations and bulking the July and August harvests permitted sufficient quantities of forage for a limited intake trial in 1973. The forage was loosely baled while fresh at each harvest, placed in a bin-type forced draft dryer at 66 C until dry. Thereafter, it was rebaled by treatment and stored for feeding.

An independent lot of hay was obtained by harvesting bermudagrass in July that had received 67 kg/ha of N from ammonium nitrate (no swine lagoon effluent). This forage was air cured and designated the control treatment. It was also used as the hay source for the preliminary intake period.

The hays were similar in leafiness and green color and visually all appeared to be of comparable quality. Prior to feeding, each hay treatment was ground through a 3.8 cm screen in a Davis mill.

Sixteen ewes (eight Dorset and eight grade Suffolk) were weighed, placed in individual pens and fed the control hay *ad libitum* for an 11-day standardization period. Two animals refused to eat and were removed from the trial. Following the standardization period, the animals were randomly assigned, within breed groups, to the four hays to be evaluated. The hays were fed *ad libitum* for a 13-day experimental period. Hay intake was determined from kgs of hay offered less kgs of weigh-back and expressed as kg of hay consumed per kg body weight. Samples of each hay were obtained daily throughout the experimental period, composited for the trial, and analyzed for dry matter, N and in vitro dry matter disappearance (IVDMD).

## Statistical Analyses

Data from the irrigated treatments were analyzed by routine analysis of variance for a randomized block. When treatments were found significant the treatment sums of squares were partitioned into linear and quadratic components to show the nature of the loading rate responses. Significant linear trends are noted. Also, when significant departures from linearity were obtained, a quadratic trend is also indicated.

Because the reference plots were somewhat removed and not randomized with the irrigated plots they were analyzed in a separate analysis. Difference, if significant, between the simulated grazing and hay treatments are so indicated. Unless otherwise stated, all statistical tests were conducted at $P \leq 0.05$. The statistical analyses used in the short-term experiments and in the animal intake trial have been explained in the respective sections.

## SOIL SAMPLING AND ANALYSIS

Soil samples were taken to a depth of 75 cm in 15 cm increments prior to initiation of the experiment to measure soil background conditions and to determine bulk density at the various depths.

Soil samples were taken quarterly from September 1973 through September 1974, and then semi-annually (usually spring and fall) starting in 1975. The quarterly samples were taken to a depth of 75 cm near two sides of the plots (two cores per plot). Starting July 1975, four cores per plot were taken within a 2-m radius from the center of the plot. Core positions were recorded at each sampling date to prevent sampling the same position at a later date. Quarterly samples were taken with a stainless steel probe, but later samples were taken by driving galvanized sampling tubes (up to 4 m long) into the soil with an electric hammer, removing them with a special jack, removing the soil cores and dividing them usually into 7.5 or 15 cm sections. Sampling dates and increments used for dividing cores are listed in Table 3. When Zn analysis was to be performed, a stainless steel probe was used to a depth of 30 cm (maximum depth for Zn analysis). Holes were refilled with a sand-bentonite mixture to exclude water from the holes.

TABLE 3. SOIL SAMPLING DATES AND SAMPLING DEPTHS

| Soil sampling date | Depth zone, cm | Sampling increment, cm | Soil sampling date | Depth zone, cm | Sampling increment, cm |
|---|---|---|---|---|---|
| May 1972 | 0-75 | 15 | Dec. 1975 | 0-225 | 15 |
| Sept. 1973 | 0-25<br>25-75 | 5<br>10 | April 1976 | 0-210 | 15 |
| Dec. 1973 | 0-25<br>25-75 | 5<br>10 | Nov. 1976 | 0-30<br>30-225 | 7.5<br>15 |
| March 1974 | 0-25<br>25-75 | 5<br>10 | April 1977 | 0-225 | 15 |
| June 1974 | 0-25<br>25-75 | 5<br>10 | Dec. 1977 | 0-30<br>30-210 | 7.5<br>15 |
| Sept. 1974 | 0-25<br>25-75 | 5<br>10 | April 1978 | 0-210 | 15 |
| July 1975 | 0-25<br>25-75<br>75-120 | 5<br>10<br>15 | Oct. 1978 | 0-30<br>30-330 | 7.5<br>15 |

Soil cores were analyzed for extractable P, K, Ca, Mg, Na, Cu, Zn, Mn and $NO_3$-N and for pH. In addition some analyses were performed for total N, organic matter, $Cl^-$, Fe and Mn.

## RAINFALL MEASUREMENTS

Rainfall was measured at the research site from April 1973 through February 1979 using a cylinder gage. A tipping bucket gage with event recorder was also used from February 1975 through February 1979. In addition, daily rainfall was recorded at a nearby site (about 2 km) with a cylinder gage. The cylinder gage at the site was used as the main data source. The tipping bucket data was mainly utilized to determine specific periods of rainfall when questions arose concerning rainfall runoff or irrigation-rainfall mixed runoff. The data from the nearby site were used for filling in missing data at the site.

## RAINFALL RUNOFF EXPERIMENTAL PROCEDURES

Rainfall runoff was collected from one-eighth the total area of the irrigated plots except for plots 4, 5 and 6 after June 1977 when runoff was collected from the whole 9.2 x 9.2 m area. The 2.3 m by 4.6 m runoff sub-plots were located at the downslope end of the irrigated plots and had borders of metal flashing as previously discussed. The sub-plot sloped to one corner where a funnel and tubing arrangement channelled the runoff to a mostly-buried 208 l barrel (Figure 2). Smaller plastic barrels were positioned inside the 208 l barrel to facilitate emptying runoff and cleaning of the barrel for small events. Plastic barrels were 88 l or 125 l depending upon the plot. After each runoff event, the runoff volume in the barrel was measured, two 180 ml samples were taken for chemical analysis while stirring the volume, and the barrels were emptied and cleaned to make ready for the next event. The samples were taken to the laboratory and refrigerated until analyses. One sample was analyzed for COD, TOC, TKN, P, $Cl^-$, $NH_3$-N and nitrate nitrogen ($NO_3$-N). The other sample was composited on a monthly basis using runoff volume for weighting and analyzed for K, Na, Ca, Mg, Cu, Zn and during some periods for Mn and Fe.

In August 1975, a collection gutter was installed across the entire downslope side of each of the runoff sub-plots of the irrigated plots. Thus, the runoff no longer had to flow to one corner of the plot for collection. The gutters were common aluminum roofing gutters and were connected with hose and tubing to the barrels. To provide a stable transition area from the sod to the gutter, and to prevent seepage down the metal gutter-soil interface, the following procedures were used. A strip of sod about 5 cm deep and 10 cm wide was removed in front of the gutter. A strip of clean plastic (6 mil) was laid down on this area and extended into the gutter. Soil was placed over the plastic to provide a sloping area from the sod to the gutter and sprayed with a soil stablizer-rock binder liquid, reactive polymer solution (XB-2391, 3M Company). A wooden board was used to cover the gutter and the bare area in front of the gutter to prevent direct gutter input of rainfall or irrigation. The gutters were cleaned often but some contamination problems existed with grass clippings washing into the gutter

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and mice and insect activities. As discussed later, small runoff volumes were not included in results largely because of the large influence of gutter cleaniness on pollutant concentrations.

In October 1975, four new reference plots were added. They were 2.3 x 4.6 m, the same dimensions as runoff sub-plots of the irrigated plots. Thus, slope length was the same. Runoff collection gutters connected to barrels as previously described were used for runoff collection.

In the spring of 1977, plots 4, 5 and 6 were modified to collect surface runoff from the whole irrigated plot and also subsurface lateral flow. These changes are described in the section on soil water movement procedures.

In October 1977 the metal borders on all plots except plots 4, 5 and 6 were removed and replaced with 2.5 cm x 15 cm wooden borders buried 10 cm in the soil. These borders were not as susceptible to damage from mowing as the previous metal flashing borders were. Wooden borders had already been installed on plots 4, 5, and 6 when the plot modifications were made earlier in 1977.

These plot modifications for rainfall runoff also apply to irrigation runoff collection. In addition, some runoff events included rainfall and irrigation. The samples were identified as rainfall runoff, irrigation runoff, or rainfall-irrigation mixed runoff.

## SUBSURFACE FLOW AND SURFACE RUNOFF - PLOTS 4, 5, 6

Because of the layered nature of the soil profile with the B horizon having much lower hydraulic conductivity than the A horizon, it was suspected that considerable subsurface lateral flow occurred at the top of the B horizon. Plots 4, 5, and 6 (Replication (Rep.) 2) were selected to monitor subsurface lateral flow (Figure 3). Modification of plots began March 17, 1977.

Perforated plastic tile (10 cm diameter) was installed at the west (downslope) end of each plot at the interface of the A-B horizon. A plastic barrier was installed around the perimeter of each plot from the surface to a depth of 85 cm which was 15 cm below the clay interface to restrict subsurface movement between plots and surrounding areas (Figure 4). The plastic barrier extended 5 cm above the surface where it was supported by a 2.5 x 15 cm wood flashing buried 10 cm deep which restricts entry of surface runoff from the surrounding areas to the plots. Surface runoff was collected on the downslope side of each plot by an aluminum gutter which extended across the entire width of each plot. Stabilization of the plot-gutter interface was similar to previously discussed methods. A metal gutter cover was used.

Subsurface runoff (tile flow) and surface runoff were funneled (gravity flow) through 5 cm PVC pipe to separate tipping bucket apparatus which recorded each tip on a mechanical counter (Figure 5). Each tip contained approximately 4.75 l of runoff. Total volume of flow was computed

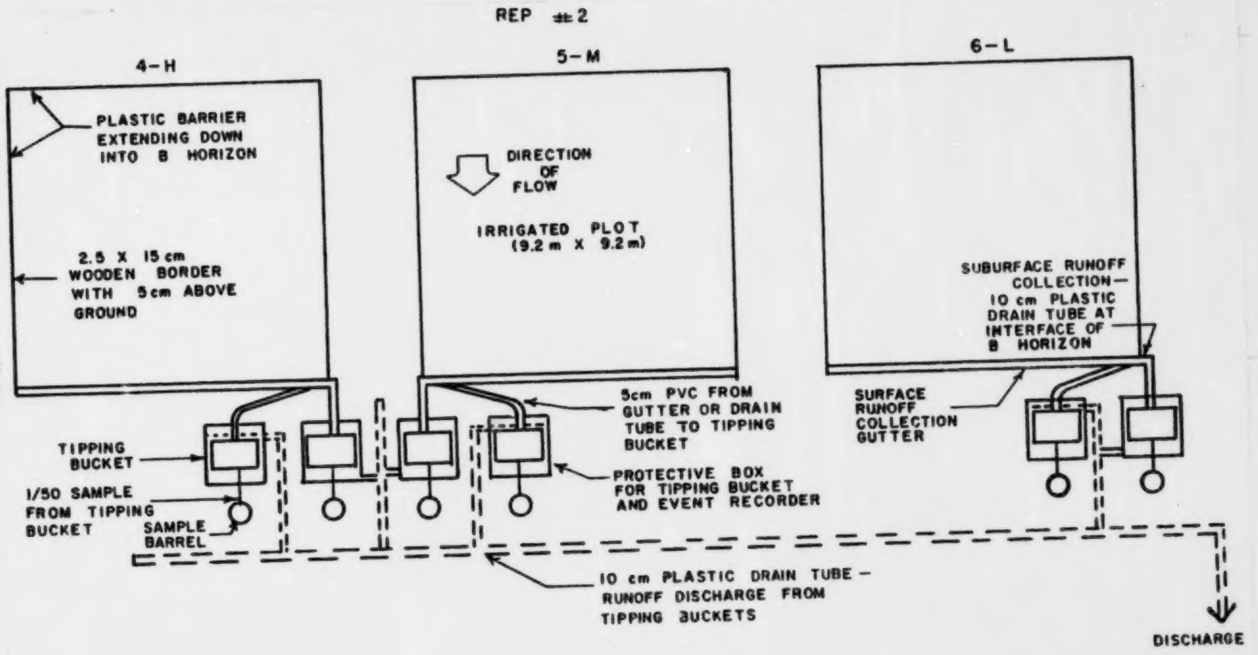
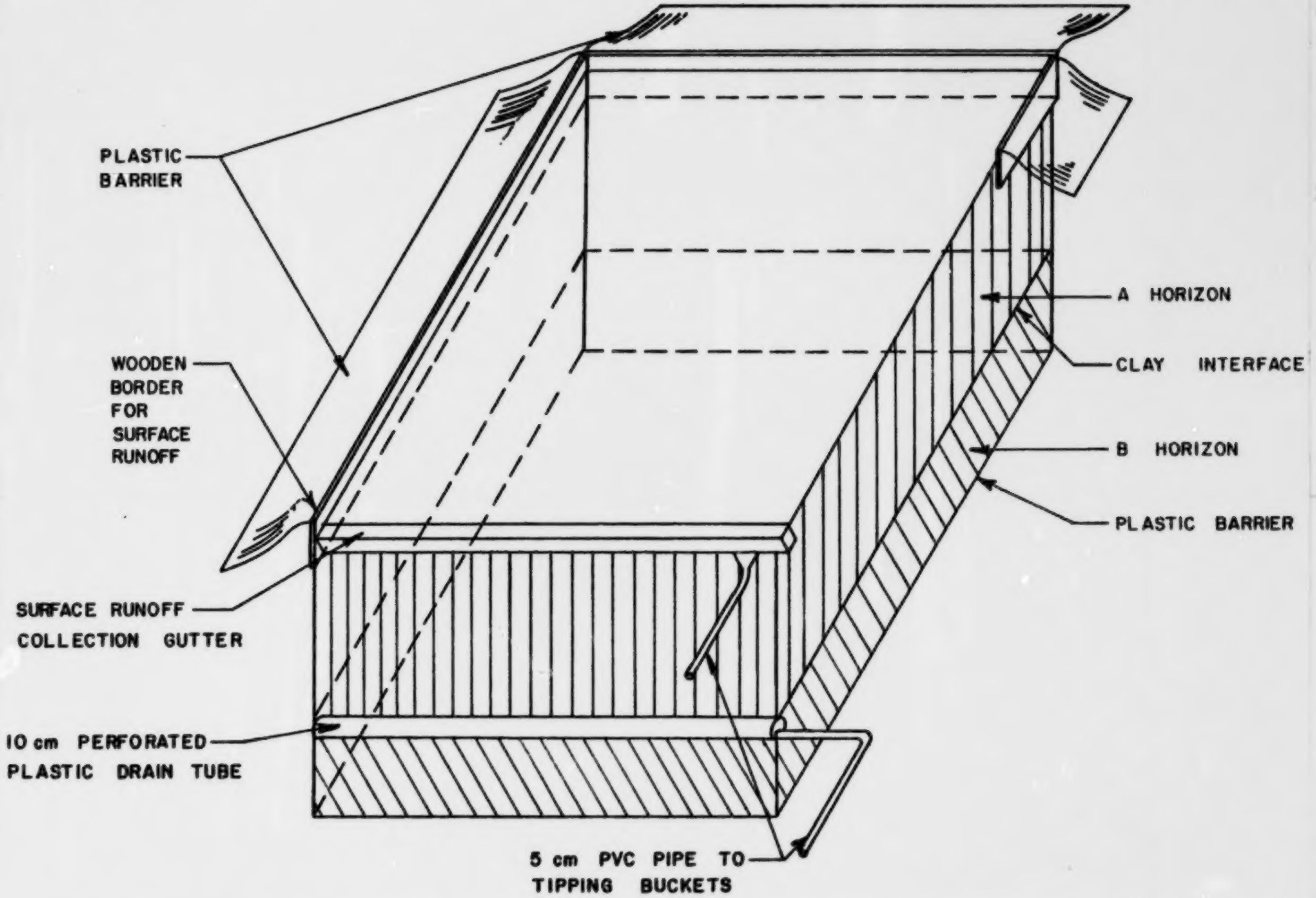

REP #2
4-H
5-M
6-L
PLASTIC BARRIER EXTENDING DOWN INTO B HORIZON
2.5 X 15 cm WOODEN BORDER WITH 5cm ABOVE GROUND
DIRECTION OF FLOW
IRRIGATED PLOT (9.2 m X 9.2 m)
SUBURFACE RUNOFF COLLECTION — 10 cm PLASTIC DRAIN TUBE AT INTERFACE OF B HORIZON
SURFACE RUNOFF COLLECTION GUTTER
TIPPING BUCKET
1/50 SAMPLE FROM TIPPING BUCKET
SAMPLE BARREL
5cm PVC FROM GUTTER OR DRAIN TUBE TO TIPPING BUCKET
PROTECTIVE BOX FOR TIPPING BUCKET AND EVENT RECORDER
10 cm PLASTIC DRAIN TUBE — RUNOFF DISCHARGE FROM TIPPING BUCKETS
DISCHARGE

Figure 3. Schematic of surface and subsurface runoff collection from plots 4, 5 and 6.


PLASTIC BARRIER
WOODEN BORDER FOR SURFACE RUNOFF
SURFACE RUNOFF COLLECTION GUTTER
10 cm PERFORATED PLASTIC DRAIN TUBE
5 cm PVC PIPE TO TIPPING BUCKETS
A HORIZON
CLAY INTERFACE
B HORIZON
PLASTIC BARRIER

Fibure 4. Schematic of plot to contain and measure surface and subsurface flow.

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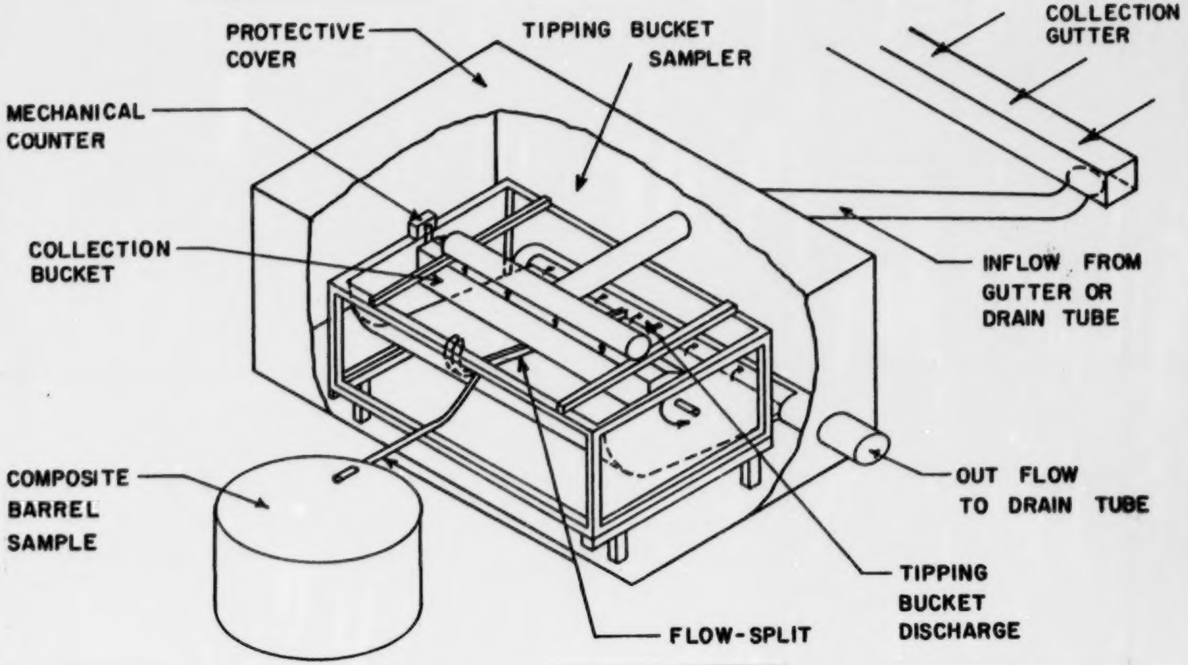
PROTECTIVE COVER
TIPPING BUCKET SAMPLER
COLLECTION GUTTER
MECHANICAL COUNTER
COLLECTION BUCKET
INFLOW FROM GUTTER OR DRAIN TUBE
COMPOSITE BARREL SAMPLE
OUT FLOW TO DRAIN TUBE
TIPPING BUCKET DISCHARGE
FLOW-SPLIT

Figure 5. Schematic of flow collector. (Flow-split is approximately 1/50 of volume from each tip).

by multiplying the number of tips recorded on the counter by the actual bucket volume per tip. A slot positioned below the tipping bucket collected about 2% of the runoff volume during each tip and composited it in a 208 l barrel. The remaining volume was removed from the sampling station via tile drainage. Event recorders were installed with each tipping bucket to record the time tipping occurred. Event recorder data was used to calculate subsurface runoff volumes during tipping bucket malfunctions. Two 180 ml samples were taken from each 208 l drum after each runoff event for chemical determinations. The remaining barrel volume was removed from the sampling area. The barrels were cleaned periodically. Installation was completed in late June 1977.

## POROUS CUP SUBSURFACE WATER SAMPLING

Soil water and nutrient concentrations within and downslope of the irrigated plots were monitored by sampling with $1 \times 10^5$ pascal ceramic cups. The sampling grid for each plot consisted of a cluster of cups located at the plot center and two at downslope locations 6.2 m and 12.4 m from the lower plot edge (Figure 6). Each cluster consisted of three cups - one at the plow sole layer which was 20 to 30 cm, one at the clay interface which was 58 to 71 cm for plots 1-6 and 41-43 cm for plots 7-9, and the third was located 25 cm into the clay layer (Figure 6). Samples were collected weekly and composited monthly for chemical analysis.

Soil water samples from the porous cups were collected on all nine plots from February 1976 through March 1977, and on plots 1-6 from July 1977 to February 1979. Soil water and constituent movement was not expected on plots 4-6 beyond the tile lines and plastic barrier; therefore, only the in-plot cups were sampled after tile installation.

Review of the porous cup data indicated that sample concentrations were variable and difficult to interpret. Often, samples could not be obtained due to insufficient soil water. Also, some samples evidently were contaminated with particles such as grass seeds when the samples were taken. In addition, the variability and bias of porous cup samples reported by Hansen and Harris (1975) and the inability of porous cup samples to represent actual soil-water concentrations as stated by Shuford et al. (1977) raise questions as to the usefulness of this data. Therefore, the data is not presented in this report.

## CHEMICAL ANALYSIS PROCEDURES

Plant samples were ashed at 500 C overnight, the ash taken up in concentrated hydrochloric acid (HCl), and the resulting solution diluted to 50 ml (final HCl normality (N) of 0.48 N). This solution was used for determination of P (colorimetrically), Na and K (flame photometry), and Ca, Mg, Na, Cu, Fe, Zn, and Mn (atomic absorption spectroscopy). Samples were extracted with 0.1 N nitric acid ($HNO_3$) plus 10% acetic acid and analyzed for $Cl^-$ using a $Cl^-$ titrator. Samples were extracted with water and analyzed for $NO_3$-N using a bacteriod suspension from soybean nodules to reduce $NO_3$-N to nitrite which was determined colorimetrically. Total N

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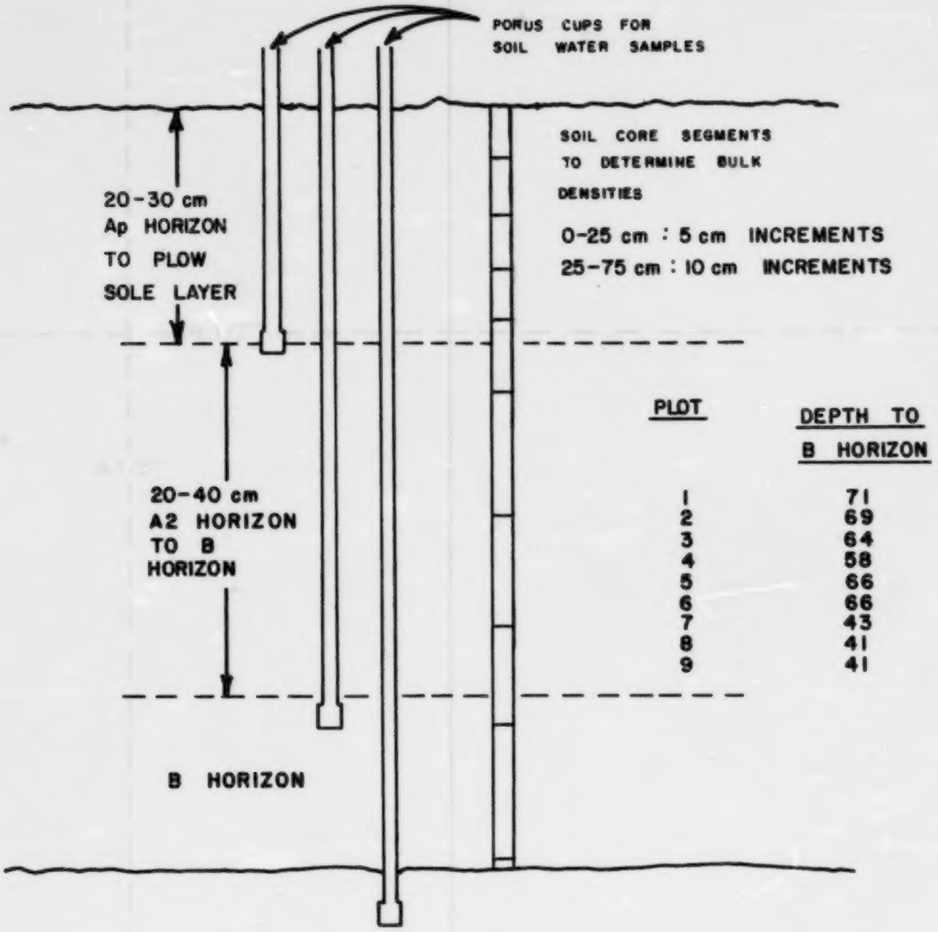
PORUS CUPS FOR SOIL WATER SAMPLES
SOIL CORE SEGMENTS TO DETERMINE BULK DENSITIES
0-25 cm : 5 cm INCREMENTS
25-75 cm : 10 cm INCREMENTS
20-30 cm Ap HORIZON TO PLOW SOLE LAYER
20-40 cm A2 HORIZON TO B HORIZON
B HORIZON

| PLOT | DEPTH TO B HORIZON |
|---|---|
| 1 | 71 |
| 2 | 69 |
| 3 | 64 |
| 4 | 58 |
| 5 | 66 |
| 6 | 66 |
| 7 | 43 |
| 8 | 41 |
| 9 | 41 |

Figure 6. Schematic of soil and water sampling profile in experimental plots.

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was determined by the Kjeldahl procedure modified to include $NO_3$-N (Jackson, 1965).

Water and lagoon effluent sample analyses were basically those of Standard Methods (1971) with modifications for automated procedures for TKN, $NH_3$-N, $NO_3$-N, $Cl^-$, P, and O-$PO_4$-P using the Technicon Auto Analyzer II (Technicon; 1973, 1974). The TKN analysis did not include $NO_3$-N. Analyses for TOC and COD were with a combination-infrared method and the dichromate reflux method, respectively. Analyses for K, Ca, Mg, Na, Cu, Zn and Mn were performed with the same methods as those used for plant samples after the water samples were evaporated to dryness.

Soil samples were air dried and extracted with water for nitrate (ultraviolet (UV) scan) and $Cl^-$ ($Cl^-$ titrator) and with 0.05 N HCl + 0.025 N sulfuric acid $H_2SO_4$) for P (colorimetrically), K and Na (flame photometry), and Ca, Mg, Cu, Zn, and Mn (atomic absorption spectroscopy). Total N was determined by the Kjeldahl procedure modified to include nitrate (Jackson, 1965), organic matter by the Walkley-Black method (Jackson, 1965), and pH on a 1:1 soil:water ratio.

As somewhat of an addendum to the procedures, it has to be noted that the procedures used for sample preparation of liquid samples for analysis of cations or metals by atomic absorption resulted in variable recovery compared to the presently-recommended EPA method. The method used for the data in this report was a dry ashing method similar to the procedure given in Standard Methods (1971) on page 416 as a tentative method. However, the presently-recommended method by both EPA and the American Public Health Association is a nitric acid wet digest procedure. These two methods were compared in 1981 using standard solutions. The recovery of K and Na was about 80% and 107%, respectively, by the dry ash method and 90% and 97%, respectively, by the wet digest methods. When the methods were compared for recovery of standard additions to lagoon liquid samples the recovery of K was about 88% for the wet digest and varied from 30% to over 100% for the dry ash method depending upon sample size and concentration. Because sample size and concentration of the lagoon liquid samples and irrigation liquid samples varied during the project a correction factor could not be applied to the data. The cation with the most error is K. Some concentration values of K in this report should be perhaps 30% to 60% higher than is reported based on the limited comparisons of the two methods.

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## SECTION 5

## RESULTS AND DISCUSSION

### RAINFALL

Monthly and annual rainfall amounts are listed in Table 4, along with the normal values for Raleigh, N.C. The growing period for Coastal bermudagrass is typically May through September. The combined rainfall for July and August was very low in 1976 and was below normal each year except for 1975 and then it was almost all in July. Another drought period was April through June in 1975. However, the irrigation of effluent averaged about 15, 30, and 60 cm for the period April through September each year and should be considered when evaluating effects of moisture conditions. Also, the irrigations were weekly and helped provide a more regular moisture input.

### IRRIGATION EFFLUENT APPLICATION

With a sprinkler irrigation system, evaporation of liquid and volatilization and oxidation of some chemical parameters are expected. This system had small sprinklers and would not be typical of larger gun-type sprinklers. Also, irrigation was normally at night in this study. Higher losses would be anticipated for daytime irrigation because of higher temperatures and wind velocities, and solar radiation. Therefore, analyses of losses and variations in measurement methods for irrigation in this study are presented to point out the possible losses and to determine accurate nutrient inputs to the soil-plant system. For the overall waste management system design, the amount of nutrients removed from the lagoon is also of importance.

#### Losses of Nutrients during Irrigation

As described in the procedures section, the method of determining nutrient application to the plots was varied during the experiment. Concentrations of nutrients in irrigation effluent collected in cups on the plots were always used for calculating nutrient loading. The amount of effluent applied to the plots was initially estimated by the amount pumped as recorded by a water meter, and assuming distribution to plots was proportional to times set on the irrigation controller.

Starting in 1976, cup volumes were collected on all plots to determine individual plot applications. Variations in volume and concentration between plots and events were sometimes large as shown for typical events in Table 5. Problems encountered with estimating application amount included (1) malfunctioning of the water meter, (2) clogging of nozzles,

## TABLE 4. MONTHLY RAINFALL

| Month | Rainfall, cm<br>Normal[+] | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | 1973-1979 Mean |
|---|---|---|---|---|---|---|---|---|---|
| Jan | 8.5 | 4.8 | 8.9 | 16.9 | 9.4 | 8.1 | 16.9 | 10.8 | 10.8 |
| Feb | 9.6 | 12.7 | 9.4 | 13.7 | 4.0 | 4.9 | 2.7 | 11.6 | 8.4 |
| Mar | 9.5 | 10.2 | 10.1 | 18.4 | 7.2 | 14.8 | 10.8 | 9.7 | 11.6 |
| Apr | 8.6 | 13.1 | 4.5 | 4.5 | 1.7 | 4.3 | 13.7 | 6.8 | 6.9 |
| May | 10.2 | 18.0 | 15.7 | 5.6 | 12.7 | 11.0 | 8.1 | 20.4 | 13.1 |
| Jun | 10.8 | 13.2 | 8.7 | 2.1 | 12.8 | 8.1 | 13.0 | 17.4 | 10.8 |
| Jul | 14.2 | 8.7 | 8.8 | 26.3 | 2.8 | 5.4 | 13.6 | 6.9 | 10.4 |
| Aug | 13.1 | 6.4 | 16.3 | 1.9 | 6.4 | 13.3 | 6.4 | 5.2 | 8.0 |
| Sep | 9.8 | 5.2 | 16.5 | 22.8 | 10.9 | 17.8 | 2.6 | 16.8 | 13.2 |
| Oct | 7.5 | 1.0 | 4.6 | 4.4 | 11.8 | 13.3 | 3.5 | 5.5 | 6.3 |
| Nov | 6.8 | 3.0 | 4.7 | 7.5 | 5.5 | 8.3 | 12.0 | 19.6 | 8.6 |
| Dec | 8.2 | 15.2 | 9.8 | 12.8 | 12.9 | 8.7 | 6.8 | 3.3 | 9.9 |
| Total | 116.8 | 111.5 | 117.9 | 136.9 | 98.0 | 119.9 | 110.1 | 134.0 | 118.1 |
| Apr-Sep | 66.7 | 64.6 | 70.5 | 63.2 | 47.3 | 59.9 | 57.4 | 73.5 | 62.4 |

[*] Rainfall data for period April 1973 through February 1979 were taken at research site, and data from a nearby site (about 2 km) were used for other months and any days of missing data at the site.

[+] Normal values are the monthly means for Raleigh, N.C. for the years 1900-1970. Source: Weather and Climate. 1971. Bulletin 396, Agricultural Experiment Station, North Carolina State University, Raleigh.

TABLE 5. EXAMPLES OF POSSIBLE INDIVIDUAL PLOT VARIATION OF EFFLUENT CUP SAMPLES

| Date | Plot #[δ] | Volume, cm[*] | Concentration in collection cups, mg/l[+] | | | | |
|---|---|---|---|---|---|---|---|
| | | | COD | TOC | TKN | $Cl^-$ | P |
| 7/2/76 | 1 | 3.19 | | | | | |
| | 4 | 2.47 | 1,130 | 480 | 209 | 116 | 67 |
| | 7 | 3.15 | | | | | |
| | 3 | 1.57 | | | | | |
| | 5 | 2.06 | | | | | |
| | 9 | 2.50 | | | | | |
| | 2 | 0.71 | 1,080 | 450 | 200 | 109 | 62 |
| | 6 | 1.32 | 1,070 | 490 | 223 | 112 | 69 |
| | 8 | 0.93 | 970 | 460 | 193 | 114 | 61 |
| 7/9/76 | 1 | 2.84 | | | | | |
| | 4 | 0.93 | 820 | 410 | 170 | 120 | 57 |
| | 7 | 3.00 | | | | | |
| | 3 | 1.36 | | | | | |
| | 5 | 1.84 | | | | | |
| | 9 | 2.85 | | | | | |
| | 2 | 0.81 | 820 | 420 | 180 | 122 | 58 |
| | 6 | 1.29 | 970 | 410 | 190 | 124 | 66 |
| | 8 | 0.92 | 890 | 420 | 172 | 136 | 61 |
| 6/3/77 | 1 | 1.51 | | | | | |
| | 4 | 1.54 | 565 | 130 | 273 | 155 | 59 |
| | 7 | 1.28 | | | | | |
| | 3 | 0.53 | | | | | |
| | 5 | 0.47 | | | | | |
| | 9 | 0.59 | | | | | |
| | 2 | 0.37 | 640 | 130 | 261 | 166 | 75 |
| | 6 | 0.35 | 610 | 120 | 240 | 163 | 68 |
| | 8 | 0.23 | 770 | 120 | 200 | 180 | 65 |
| 6/11/77 | 1 | 0.77 | 440 | 240 | 273 | 129 | 54 |
| | 4 | 1.21 | 480 | 200 | 303 | 143 | 56 |
| | 7 | 1.17 | 440 | 210 | 283 | 131 | 53 |
| | 3 | 0.21 | 410 | 240 | 180 | 126 | 50 |
| | 5 | 0.23 | 410 | 240 | 189 | 124 | 50 |
| | 9 | 0.37 | 410 | 160 | 243 | 126 | 51 |
| | 2 | 0.21 | 510 | 250 | 205 | 140 | 61 |
| | 6 | 0.19 | 570 | 260 | 168 | 140 | 50 |
| | 8 | 0.19 | 550 | 280 | 152 | 133 | 50 |

[δ] Plots 1, 4, 7 = High; 3, 5, 9 = Medium; 2, 6, 8 = Low treatment.

[*] Results are for average of four cups per plot.

[+] Sample for each plot was composite from four cups.

(3) pressure variation, especially when two plots were irrigated at the same time, (4) wind effects on distribution pattern, (5) rainfall mixed with effluent when rain occurred the night of irrigation, and (6) evaporation and volatilization from the cups from the time of irrigation to the time of sample collection. The effects of some of these factors were investigated and are presented in Appendix A.

The application rate of lagoon effluent was based on nitrogen. The lagoon TKN typically consisted of about 90% $NH_3$-N and 10% organic nitrogen. Since $NH_3$-N can be volatilized as ammonia, the loss of N during irrigation is important when determining what actually is applied to the plots. An estimate of N losses can be made by comparing TKN concentrations in the lagoon effluent and the collection cup liquid. Using this comparison, TKN losses are often 20% or more (Table 6). This loss should be essentially all $NH_3$-N which means $NH_3$-N percent reduction is even greater than TKN percent reduction. This is shown in Table 7 for 1978 and 1979. $NH_3$-N volatilization would be affected by pH of effluent, air temperature and wind speed, sprinkler drop size, and pH of soil. The pH of effluent was measured in 1978 and was between 7.3 and 8.0 for May through September.

TABLE 6. IRRIGATION LOSSES OF TKN*

| Month | 1976 | 1977+ | 1978δ | 1979δ | Mean |
|---|---|---|---|---|---|
| April | 14 | 13 | - | 4 | 10 |
| May | 20 | 34 | 16 | 2 | 18 |
| June | 16 | 38 | 30 | 6 | 22 |
| July | 22 | 31 | 25 | 8 | 22 |
| August | 27 | 46 | 19 | 14 | 26 |
| September | 16 | 39 | 27 | 22 | 26 |
| Mean | 19 | 34 | 23 | 9 | 21 |

*Only used data from weeks which had both lagoon and irrigation cup values (matched pairs) and losses were based on concentration only.

+In 1977, there were eight daytime irrigations; two each in April, May, June, and July.

δCollection cups for irrigation had funnels to reduce evaporation and ammonia volatilization.

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### TABLE 7. NITROGEN LOSSES OF TKN AND $NH_3$-N

| Month | n[*] | Lagoon concentration, mg/l |  | $NH_3$-N/TKN | Reduction in concentration in collection cups, %[+] |  |
|---|---|---|---|---|---|---|
|  |  | TKN | $NH_3$-N |  | TKN | $NH_3$-N |
| 1978 |  |  |  |  |  |  |
| May | 4 | 346 | 326 | 0.94 | 16 | 16 |
| June | 3 | 381 | 378 | 0.99 | 30 | 37 |
| July | 3 | 361 | 350 | 0.97 | 25 | 29 |
| August | 3 | 285 | 277 | 0.97 | 19 | 21 |
| September | 4 | 286 | 257 | 0.90 | 27 | 25 |
| Mean |  | 332 | 318 | 0.96 | 23 | 26 |
| 1979[δ] |  |  |  |  |  |  |
| April | 2 | 146 | 124 | 0.85 | 4 | 13 |
| May | 2 | 94 | 64 | 0.68 | 2 | 6 |
| June | 6 | 158 | 149 | 0.94 | 6 | 14 |
| July | 2 | 202 | 195 | 0.96 | 8 | 21 |
| August | 4 | 203 | 194 | 0.96 | 14 | 22 |
| September | 2 | 184 | 166 | 0.90 | 22 | 25 |
| Mean |  | 164 | 149 | 0.91 | 9 | 17 |

[*] Only used data from weeks which had both values (matched pairs). Number of matched pairs equals n.

[+] Losses based on concentration; evaporation losses not included. Irrigation was at night and collection cups had funnel inserts to reduce evaporation and volatilization after collection. Plot concentrations for each event used were averages of four plots with four cups per plot.

[δ] Concentrations are lower in 1979 than in 1978 because an aerator was run January through April 1979.

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Irrigation losses of other nutrients or chemical parameters are shown in Table 8. If no mass loss of a parameter occurred, but evaporation of irrigated effluent did occur, then the ratio of concentration in the cup to concentration in the lagoon should be greater than 1.0. This is generally the case for the annual mean ratio for the cations (K, Ca, etc.). $Cl^-$, which should be a good indicator for evaporation, had annual ratios close to 1.0. The ratios for COD were often less than 1.0, but showed much variation. In general, the variations in the monthly ratios were large. Source of this variation could include sampling differences, especially of the lagoon, changes in parameters during sample transport and storage, and laboratory analyses errors.

## Annual Application Amounts of Nutrients

As previously mentioned, the method of calculating annual amounts of nutrients applied by irrigation was not the same every year. Considering the variables involved and the variation in the concentration and volume data, the estimates of annual application amounts can easily be ± 10% different from the actual amount applied. Also, the actual volatilization and other losses from the vegetation and soil surface could not be measured except for runoff.

Application rates at the start of the irrigation season were based on lagoon TKN concentration and the predetermined desired N rates of 336, 672 and 1345 kg/ha. Lagoon concentration varied during the season and from year to year. Monthly mean concentrations for 1976-1979 are given in Table 9, while yearly mean concentrations for 1973-1979 are given in Table 10. The lagoon had been in operation about 12 years when this study was started and had only about 1 m of liquid above the sludge. Concentrations of N increased in the lagoon from 1973 through 1975. In November 1975, the lagoon was cleaned out and reloading of the lagoon began in December. Nitrogen concentration was low at the start of the 1976 irrigation season but increased enough during the season to have a mean concentration similar to 1973. The lagoon was relatively stable in 1977 and 1978. The low N concentrations in 1979 are mainly due to operating an areator in the lagoon January through April. The aerator was discontinued in April but the N concentrations remained below 200 mg/l the rest of the irrigation season.

Concentrations of the various other minerals in the effluent shown in Table 10 also decreased after the lagoon was cleaned out except for Na. K and Mg remained lower than the 1973-1975 levels (pre-cleanout) for the rest of the study period. P tended to remain the same and even increased after the aerator was run in 1979. Thus, the N:P:K ratios varied, especially after 1975. The N:P:K ratios of the mean concentrations for 1973-1979 was 1:0.25:0.85. The concentrations of COD, TOC, and $O\text{-}PO_4\text{-}P$ in cup effluent are shown in Table 11 for 1978 and 1979. The P in the lagoon effluent was largely in the $O\text{-}PO_4\text{-}P$ form and should be essentially as available to plants as commercial fertilizers.

Because of variation in concentration and the problem of missing concentration data when rainfall was mixed in with effluent in the cups, monthly mean concentrations were used for calculating amount of minerals

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## TABLE 8. CONCENTRATION DIFFERENCE BETWEEN LAGOON SAMPLE AND COLLECTION CUP LIQUID

| | | Monthly mean concentration ratio of collection cup liquid to lagoon sam | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Year | Month | COD* | TOC* | P* | $Cl^-$* | K | Ca | Mg | Na | Cu | Zn |
| 1976 | May | 0.69 | 0.64 | 1.10 | 0.76 | 0.39 | 1.07 | 1.19 | 1.49 | 0.39 | 1.24 |
| | June | 0.92 | 1.20 | 0.88 | 0.87 | 0.99 | 1.08 | 2.00 | 1.88 | 0.36 | 0.72 |
| | July | 1.13 | 0.93 | 0.77 | 1.02 | 1.03 | 1.15 | 1.52 | 1.21 | 1.11 | 1.42 |
| | Aug. | 0.97 | 0.89 | 0.63 | 1.31 | 1.02 | 0.95 | 0.85 | 0.96 | 1.80 | 1.75 |
| | Sept. | 0.84 | 1.12 | 0.81 | 1.19 | 1.66 | 0.84 | 0.11 | 1.28 | 0.52 | 0.17 |
| | Mean | 0.91 | 0.96 | 0.84 | 1.03 | 1.02 | 1.02 | 1.13 | 1.36 | 0.84 | 1.06 |
| | Std. Dev. | 0.16 | 0.22 | 0.17 | 0.22 | 0.46 | 0.12 | 0.71 | 0.35 | 0.62 | 0.62 |
| 1977 | April | 0.92 | 0.95 | 1.02 | 1.11 | 1.72 | 1.45 | 2.40 | 0.90 | 0.93 | 1.35 |
| | May | 1.31 | 1.58 | 0.99 | 1.17 | 1.96 | 1.20 | 2.40 | 0.73 | 1.27 | 2.30 |
| | June | 0.96 | 1.10 | 0.70 | 0.91 | 1.15 | 0.89 | 0.92 | 0.92 | 1.27 | 1.77 |
| | July | 0.81 | 1.18 | 0.60 | 0.89 | 0.87 | 1.09 | 0.42 | 1.06 | 1.14 | 1.40 |
| | Aug. | 0.82 | 1.15 | 0.42 | 0.94 | 0.71 | 0.92 | 0.74 | 1.02 | 0.17 | 2.23 |
| | Sept. | 0.65 | 1.59 | 0.59 | 0.94 | 1.81 | 0.88 | 0.60 | 0.97 | 1.13 | 2.31 |
| | Oct. | 0.97 | - | 0.47 | 0.83 | 1.20 | 1.03 | 1.67 | 1.08 | 1.50 | 2.14 |
| | Mean | 0.92 | 1.26 | 0.68 | 0.97 | 1.35 | 1.07 | 1.31 | 0.95 | 1.06 | 1.93 |
| | Std. Dev. | 0.20 | 0.26 | 0.24 | 0.12 | 0.49 | 0.21 | 0.84 | 0.12 | 0.43 | 0.42 |
| 1978 | May | 0.80 | 1.10 | 0.65 | 0.88 | 1.22 | 1.02 | 1.33 | 1.07 | 1.75 | 0.95 |
| | June | 1.07 | 1.10 | 0.50 | 1.00 | 0.97 | 0.90 | 1.27 | 1.08 | 1.17 | 1.11 |
| | July | 1.04 | 1.09 | 0.58 | 0.98 | 0.86 | 0.78 | 0.29 | 0.92 | 0.50 | 1.09 |
| | Aug. | 1.23 | 0.72 | 0.64 | 0.95 | 1.03 | 0.91 | 0.85 | 1.20 | 0.78 | 0.90 |
| | Sept. | 1.17 | 0.53 | 0.62 | 0.98 | 1.01 | 0.97 | 0.44 | 1.16 | 0.78 | 0.54 |
| | Mean | 1.06 | 0.91 | 0.60 | 0.96 | 1.02 | 0.92 | 0.84 | 1.09 | 1.00 | 0.92 |
| | Std. Dev. | 0.16 | 0.27 | 0.06 | 0.05 | 0.13 | 0.09 | 0.47 | 0.11 | 0.48 | 0.23 |
| 1979 | April | 1.44 | 1.32 | 1.20 | 1.01 | 0.93 | 0.89 | 1.30 | 1.07 | 0.77 | 1.06 |
| | May | 0.78 | 0.84 | 0.99 | 1.03 | 1.22 | 0.92 | 0.96 | 0.95 | 1.71 | 1.39 |
| | June | 1.01 | 1.01 | 0.83 | 1.03 | 1.17 | 0.93 | 0.89 | 1.05 | 1.00 | 0.54 |
| | July | 0.93 | 1.02 | 0.89 | 1.00 | 2.26 | 0.83 | 0.52 | 0.90 | 0.91 | 2.23 |
| | Aug. | 0.99 | 1.11 | 0.80 | 0.98 | 1.53 | 0.86 | 0.55 | 0.88 | 0.42 | 1.56 |
| | Sept. | 0.78 | 0.81 | 0.73 | 1.02 | 2.68 | 0.93 | 0.95 | 0.86 | 1.00 | 2.82 |
| | Mean | 0.99 | 1.02 | 0.91 | 1.01 | 1.63 | 0.89 | 0.86 | 0.95 | 0.97 | 1.60 |
| | Std. Dev. | 0.24 | 0.19 | 0.17 | 0.02 | 0.69 | 0.04 | 0.29 | 0.09 | 0.42 | 0.82 |

*Monthly mean ratio calculated from ratios of matched paris for events that had both lagoon and cup data. Other ratios are calculated from mean monthly concentrations and the number of samples for lagoon and for cup may be different.

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TABLE 9. MONTHLY MEAN EFFLUENT CONCENTRATIONS FOR COLLECTION CUPS ON PLOTS[§]

| Year | Month | n[*] | Concentration of element, mg/l |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | N | P | K | Ca | Mg | Na | $Cl^-$ | Cu | Zn |
| 1976 | Apr | 3 | 121 | 38 | 103 | 51 | 26 | 134 | 91 | 0.34 | 0.24 |
|  | May | 3 | 117 | 42 | 64 | 45 | 25 | 133 | 94 | 0.19 | 0.46 |
|  | Jun | 3,2-3 | 164 | 59 | 164 | 65 | 36 | 186 | 104 | 0.41 | 0.51 |
|  | Jul | 5,2 | 213 | 67 | 270 | 83 | 38 | 204 | 136 | 0.50 | 0.54 |
|  | Aug | 4,2 | 234 | 64 | 178 | 70 | 23 | 192 | 155 | 0.18 | 0.28 |
|  | Sep | 3 | 252 | 64 | 298 | 47 | 10 | 225 | 156 | 0.22 | 0.11 |
| 1977 | Apr | 2,6[+] | 287 | 108 | 151 | 42 | 12 | 130 | 152 | 0.14 | 0.23 |
|  | May | 3,6[+] | 254 | 88 | 151 | 42 | 12 | 130 | 166 | 0.14 | 0.23 |
|  | Jun | 5,6[+] | 231 | 61 | 151 | 42 | 12 | 130 | 140 | 0.14 | 0.23 |
|  | Jul | 6 | 299 | 58 | 150 | 49 | 13 | 157 | 154 | 0.08 | 0.28 |
|  | Aug | 3,2 | 202 | 49 | 116 | 36 | 14 | 154 | 154 | 0.06 | 0.29 |
|  | Sep | 4,4[†] | 193 | 53 | 159 | 30 | 15 | 128 | 133 | 0.09 | 0.30 |
|  | Oct | 1,4[†] | 178 | 42 | 159 | 30 | 15 | 128 | 116 | 0.09 | 0.30 |
| 1978 | May | 4,2 | 290 | 62 | 151 | 47 | 12 | 130 | 141 | 0.14 | 0.35 |
|  | Jun | 3,4 | 267 | 56 | 169 | 45 | 14 | 136 | 144 | 0.14 | 0.39 |
|  | Jul | 3 | 272 | 58 | 178 | 35 | 5 | 113 | 132 | 0.10 | 0.24 |
|  | Aug | 3,2 | 232 | 54 | 153 | 32 | 17 | 171 | 122 | 0.14 | 0.18 |
|  | Sep | 4,3 | 210 | 54 | 176 | 29 | 8 | 151 | 143 | 0.14 | 0.13 |
| 1979 | Apr | 2 | 140 | 84 | 71 | 71 | 26 | 160 | 120 | 0.64 | 1.35 |
|  | May | 2 | 92 | 101 | 115 | 46 | 26 | 160 | 128 | 0.12 | 0.25 |
|  | Jun | 6 | 149 | 74 | 70 | 40 | 16 | 147 | 139 | 0.12 | 0.14 |
|  | Jul | 2 | 186 | 80 | 104 | 34 | 11 | 132 | 142 | 0.10 | 0.29 |
|  | Aug | 4 | 174 | 76 | 92 | 32 | 11 | 134 | 144 | 0.05 | 0.36 |
|  | Sep | 2 | 144 | 61 | 99 | 28 | 20 | 132 | 136 | 0.06 | 0.62 |

[§] Monthly means calculated using one mean value for each irrigation event that had data and no rainfall mixed in. Each event mean was calculated from 4 or more plots, four cups per plot for N, P and $Cl^-$ and only one plot was used for other chemical analyses. In 1978 and 1979, cups had funnel inserts.

[*] When two numbers are separated by a comma, the first number is the number of irrigation events with analyses for N, P, and $Cl^-$ and the second number is for all other chemical analyses.

[+] Six events included one from May and five from June.

[†] Four events included three from Sept. and one from Oct.

TABLE 10. ANNUAL MEAN CONCENTRATION OF EFFLUENT COLLECTED IN CUPS ON PLOT[†]

| | Irrigated effluent concentration, mg/l | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Year | N | P | K | Ca | Mg | Na | $Cl^-$ | Cu | Zn |
| 1973 | 212 | 49 | 220 | 52 | 62 | 86 | 139 | 0.50 | -- |
| 1974 | 272 | 49 | 274 | 55 | 55 | 113 | 187 | 0.40 | -- |
| 1975 | 300 | 63 | 288 | 68 | 49 | 138 | -- | 0.40 | 0.40 |
| 1976[‡] | 202 | 59 | 203 | 61 | 24 | 190 | 132 | 0.30 | 0.34 |
| 1977 | 255 | 62 | 150 | 42 | 13 | 148 | 146 | 0.10 | 0.26 |
| 1978[§] | 250 | 57 | 166 | 37 | 12 | 143 | 135 | 0.13 | 0.13 |
| 1979[∓, §] | 148 | 79 | 91 | 38 | 17 | 143 | 137 | 0.12 | 0.34 |
| Mean | 234 | 59 | 199 | 51 | 33 | 137 | 143 | 0.28 | 0.29 |

[†] Effective mean calculated by dividing total mass applied by total volume applied.

[‡] Lagoon was cleaned out in November 1975; loading started again in December 1975.

[∓] Lagoon was mechanically aerated January through April in 1979 resulting in low nitrogen concentration that remained low during most of irrigation period.

[§] In 1978 and 1979, cups had funnel inserts to reduce evaporation and volatilization.

applied. The monthly application of effluent (cm) and the associated monthly mean concentrations of minerals are given for 1976-1979 in Tables 12 and 9, respectively. Monthly applications were fairly uniform during each year except for September 1976 on plots 1 and 4 when the irrigation control was accidently left on all night, and July 1977 and June 1979 when the applications were increased because of lagging behind the schedule due mainly to low lagoon concentrations. Thus, although seasonal rates of N approached the desired levels, distribution of effluent and applied N was not always uniform.

The amounts of effluent applied for each N rate each year and the quantities of N and other minerals applied are shown in Table 13. Because of variation in lagoon concentration and other variables previously discussed, the N rates only approximated the desired rates of 336, 672, and 1345

## TABLE 11. MONTHLY MEAN CONCENTRATIONS OF COD, TOC, AND O-$PO_4$-P IN COLLECTION CUPS

| | | | Concentration of element, mg/l | | | |
|---|---|---|---|---|---|---|
| Year | Month | n* | COD | TOC | O-$PO_4$- P | O-$PO_4$-P/P |
| 1978 | May | 4 | 650 | 184 | 52 | 0.84 |
| | June | 3 | 630 | 167 | 51 | 0.91 |
| | July | 3 | 420 | 110 | 48 | 0.83 |
| | August | 3 | 430 | 90 | 50 | 0.92 |
| | Sept. | 4 | 360 | 133 | 48 | 0.89 |
| 1979 | April | 2 | 940 | 419 | 76 | 0.90 |
| | May | 2 | 420 | 232 | 96 | 0.95 |
| | June | 6 | 360 | 133 | 67 | 0.90 |
| | July | 2 | 280 | 79 | 58 | 0.72 |
| | August | 4 | 320 | 134 | 53 | 0.70 |
| | Sept. | 2 | 310 | 121 | 56 | 0.92 |

*n is number of irrigation events from which monthly mean was calculated.

kg/ha. Nitrogen levels applied in 1974 and 1975 exceeded the desired rates, but since the pumped volume was used these years without allowance for any irrigation evaporation losses, the calculated rates are likely somewhat higher than what actually fell on the plots. Except for 1979, cm of effluent applied were nearly the same for all years. The three N rates required approximately 0.5, 1 and 2 cm effluent applied per week for the low, medium and high rates, respectively.

The seven-year means (Table 13) show application rates of N to be very close to desired rates. The quantities of other minerals applied are reather large when compared to normal fertilization rates.

Some irrigation runoff occurred but was on the order of 0 to 5% as estimated from collection from the runoff subplot. The application amounts calculated in this section do not include adjustment for runoff. Very few significant irrigation runoff events occurred after the first year (1973). However, the high pollution potential of irrigation runoff makes it essential to avoid this runoff when possible. Thus, instead of a set irrigation schedule for a farm operation, the schedule should be varied to avoid rainy periods or periods when the soil is saturated. The amounts of

TABLE 12. MONTHLY IRRIGATION AMOUNTS 1976 - 1979[δ]

| | | | Plot irrigation amounts, cm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | High application plots | | | Medium application plots | | | Low application plots | | |
| Year | Month | n[φ] | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 |
| 1976 | Apr | 3 | 4.37 | 4.60 | 5.33 | 2.48 | 2.48 | 2.68 | 1.29 | 1.57 | 1.47 |
| | May | 4 | 5.18 | 7.13 | 6.42 | 2.68 | 2.80 | 4.26 | 1.62 | 1.77 | 1.48 |
| | Jun | 4 | 9.04 | 7.06 | 8.74 | 3.83 | 4.86 | 6.41 | 2.75 | 2.83 | 2.67 |
| | Jul | 4[†] | 8.22 | 4.69 | 7.55 | 4.66 | 7.32 | 8.56 | 2.27 | 3.68 | 3.44 |
| | Aug | 5[‡] | 11.59 | 9.56 | 11.05 | 4.54 | 6.92 | 7.39 | 2.54 | 2.76 | 3.15 |
| | Sep | 3 | 17.99[*] | 17.15[*] | 12.82 | 4.72 | 5.42 | 7.19 | 2.85 | 3.70 | 2.96 |
| Total | | 23 | 56.39 | 50.19 | 51.91 | 22.91 | 29.80 | 36.49 | 13.32 | 16.31 | 15.17 |
| 1977 | Apr | 2 | 2.38 | 1.68 | 2.71 | 1.23 | 1.26 | 0.95 | 1.82 | 0.68 | 0.98 |
| | May | 5 | 5.84 | 6.56 | 5.40 | 3.39 | 3.34 | 3.46 | 2.40 | 2.18 | 1.83 |
| | Jun | 5 | 6.52 | 8.34 | 5.34 | 2.99 | 2.97 | 3.69 | 1.71 | 1.70 | 1.60 |
| | Jul | 7[#] | 19.07 | 19.73 | 28.25 | 6.43 | 7.85 | 13.47 | 4.46 | 3.94 | 7.30 |
| | Aug | 3 | 2.73 | 2.35 | 2.65 | 1.88 | 1.22 | 1.73 | 0.84 | 0.93 | 0.97 |
| | Sep | 4 | 7.27 | 4.89 | 6.85 | 2.70 | 3.93 | 4.02 | 2.51 | 1.60 | 2.37 |
| | Oct | 1 | 1.18 | 1.56 | 1.21 | 0.77 | 1.16 | 0.85 | 0.72 | 0.58 | 0.73 |
| Total | | 27 | 44.99 | 45.11 | 52.41 | 19.39 | 21.73 | 28.17 | 14.46 | 11.61 | 15.78 |
| 1978[§] | May | 5 | 7.14 | 4.32 | 8.37 | 5.16 | 2.99 | 2.92 | 2.16 | 1.59 | 1.73 |
| | Jun | 5 | 8.83 | 9.41 | 13.04 | 4.08 | 3.54 | 4.22 | 2.68 | 1.30 | 1.24 |
| | Jul | 4 | 8.70 | 10.73 | 11.77 | 3.99 | 4.11 | 4.82 | 1.84 | 1.43 | 1.67 |
| | Aug | 4 | 10.35 | 12.43 | 14.12 | 6.52 | 6.92 | 6.21 | 3.13 | 1.90 | 2.74 |
| | Sep | 5 | 10.09 | 12.04 | 6.10 | 4.83 | 5.11 | 6.61 | 3.08 | 2.60 | 2.23 |
| Total | | 23 | 45.11 | 48.93 | 53.40 | 24.58 | 22.67 | 24.78 | 12.89 | 8.82 | 9.61 |
| 1979[§] | Apr | 2 | 4.68 | 3.41 | 4.15 | 3.83 | 1.34 | 2.34 | 1.01 | 1.21 | 1.12 |
| | May | 5 | 16.18 | 13.85 | 16.15 | 9.66 | 6.31 | 9.24 | 3.55 | 5.01 | 4.79 |
| | Jun | 8 | 28.37 | 27.85 | 31.57 | 15.99 | 12.59 | 15.99 | 5.96 | 7.90 | 5.83 |
| | Jul | 4 | 15.44 | 10.21 | 14.98 | 7.40 | 7.45 | 8.14 | 3.35 | 3.82 | 3.70 |
| | Aug | 5 | 16.38 | 15.23 | 15.07 | 7.86 | 6.50 | 8.68 | 4.68 | 3.84 | 2.74 |
| | Sep | 4 | 10.14 | 10.40 | 9.90 | 4.78 | 4.10 | 4.82 | 3.05 | 2.14 | 2.37 |
| Total | | 28 | 91.19 | 80.95 | 91.82 | 49.52 | 38.29 | 46.72 | 21.60 | 23.92 | 20.55 |

[δ] Estimated from cup volumes, normally four cups per plot for four plots each irrigation event.

[φ] Number of events for month.

[†] Plots 2, 6, & 7 had only three irrigations and plot 5 had five irrigations.

[‡] Medium rate plots (3, 5, 9) received four irrigations.

[*] Plots 1 and 4 received 13.46 cm. each on 9/11/76 because sprinkler system was left on overnight.

[#] Plots 7 & 8 received eight irrigations.

[§] In 1978 and 1979, cups had funnel inserts to reduce evaporation.

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## TABLE 13. ANNUAL IRRIGATION APPLICATION AMOUNTS

| Year | Treatment | Effluent applied, cm | Amount of element applied, kg/ha[†] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | N | P | K | Ca | Mg | Na | $Cl^-$ | Cu | Zn |
| 1973 | Low | 13.7 | 297 | 67 | 301 | 71 | 83 | 118 | 190 | 0.67 | --[‡] |
| | Medium | 27.4 | 593 | 135 | 603 | 141 | 166 | 235 | 382 | 1.34 | -- |
| | High | 54.8 | 1,185 | 268 | 1,205 | 282 | 332 | 470 | 763 | 2.69 | -- |
| 1974 | Low | 15.2 | 398 | 74 | 408 | 82 | 83 | 170 | 274 | 0.67 | -- |
| | Medium | 30.4 | 795 | 148 | 815 | 164 | 166 | 341 | 548 | 1.34 | -- |
| | High | 60.8 | 1,590 | 296 | 1,631 | 327 | 332 | 680 | 1,095 | 2.68 | -- |
| 1975 | Low | 14.3 | 429 | 90 | 411 | 97 | 70 | 197 | -- | 0.60 | 0.58 |
| | Medium | 28.6 | 858 | 179 | 823 | 195 | 140 | 395 | -- | 1.21 | 1.17 |
| | High | 57.2 | 1,716 | 358 | 1,646 | 389 | 280 | 789 | -- | 2.40 | 2.33 |
| 1976 | Low | 14.9 | 297 | 88 | 304 | 95 | 40 | 286 | 193 | 0.47 | 0.54 |
| | Medium | 29.7 | 598 | 177 | 598 | 188 | 79 | 561 | 387 | 0.94 | 1.08 |
| | High | 52.8 | 1,075 | 310 | 1,072 | 311 | 120 | 1,001 | 702 | 1.57 | 1.66 |
| 1977 | Low | 14.0 | 351 | 89 | 209 | 58 | 18 | 190 | 206 | 0.14 | 0.37 |
| | Medium | 23.1 | 581 | 144 | 346 | 97 | 30 | 328 | 341 | 0.23 | 0.61 |
| | High | 47.5 | 1,223 | 294 | 712 | 204 | 62 | 737 | 703 | 0.47 | 1.26 |
| 1978 | Low | 10.4 | 260 | 59 | 172 | 38 | 12 | 152 | 142 | 0.14 | 0.14 |
| | Medium | 24.0 | 597 | 136 | 397 | 87 | 28 | 341 | 325 | 0.32 | 0.32 |
| | High | 49.2 | 1,234 | 278 | 815 | 181 | 57 | 702 | 665 | 0.64 | 0.64 |
| 1979 | Low | 22.0 | 324 | 176 | 202 | 85 | 38 | 316 | 301 | 0.27 | 0.75 |
| | Medium | 44.8 | 664 | 357 | 409 | 174 | 76 | 644 | 614 | 0.57 | 1.52 |
| | High | 88.0 | 1,305 | 695 | 796 | 337 | 148 | 1,261 | 1,207 | 1.07 | 2.93 |
| Avg. | Low | 14.9 | 337 | 92 | 287 | 75 | 49 | 204 | 218 | 0.42 | 0.48 |
| | Medium | 29.7 | 669 | 182 | 570 | 137 | 98 | 406 | 433 | 0.85 | 0.94 |
| | High | 58.6 | 1,333 | 357 | 1,125 | 290 | 190 | 806 | 856 | 1.65 | 1.76 |

[†] Each value is the mean of three replications.

[‡] Values not determined.

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irrigation runoff and rain-irrigation mixed runoff are presented in the section on runoff results.

## CROP RESPONSE

Coastal bermudagrass is a perennial grass which can utilize a relatively large amount of N, which is normally the limiting constituent in land application of lagoon effluent, and it responds well to irrigation. It is a deep-rooted, long-lived perennial which has a hot-weather growth period (April - September) and requires a well-drained soil. The application of nutrients and water via weekly applications of lagoon effluent during the growing season should have tended to maximize nutrient utilization. However, it was not known what effects high rates of nutrient application in this manner would have on forage yield and quality, especially when continuing the high applications for several years.

The three predetermined N rates of 336, 672, and 1345 kg/ha/yr required approximately 0.5, 1, and 2 cm of lagoon effluent, respectively, applied per week during the growing season. The effluent application rate varied somewhat during each year because of variation in lagoon N concentrations resulting mainly from climatic effects and changes in swine live weight in the housing unit. Also, major reductions in lagoon N concentration resulted from cleaning out the lagoon in November 1975 and operating an aerator January - April 1979. The variations in concentration caused variation in weekly application rates of the effluent and associated nutrients. The interactions of varying nutrient and effluent application rates, climatic conditions, and stage of vegetative growth probably caused some of the differences in yield. However, most of the variation in application rates would be expected with any swine lagoon-irrigation system.

A typically recommended fertilization rate in North Carolina for high yields of good-quality Coastal bermudagrass hay is about 240 kg N, 60 kg $P_2O_5$, and 120 kg $K_2O$ per ha (Dobson et al., 1977). This is a N:P:K ratio of 1:0.11:0.42. Overall, the seven-year mean application rates of N in this study were 337, 669, and 1,333 kg/ha. The mean N:K:P ratio was 1:0.27: 0.85. Thus, not only were large amounts of N applied, but large amounts of P and K were applied and in a higher ratio to N than is normally recommended. Also, large quantities of other minerals such as Ca and Mg were applied.

From an agronomic fertilization standpoint, fertilization with the swine lagoon-irrigation system in this study was different from typical fertilization of a pasture or hay field of Coastal bermudagrass in several ways. The nutrient input in this study was via liquid and was fairly constant and uniform in weekly applications throughout the growing season, irrigation water was applied weekly, and large quantities of nutrients in unusual ratios were applied.

### Dry Matter Yields

Under dry land conditions in the coastal plains of North Carolina little yield response is obtained from N applications above 336 kg/ha (Woodhouse, 1969). The addition of supplemental water would likely increase yields by approximately 20 to 25% and permit some additional response from slightly higher N application. The low N level selected for this study (336 kg/ha) was actually the highest rate recommended for dry land conditions. However, the presence of supplemental water was anticipated to provide yield responses from the higher rates evaluated. This, of course, assumed no detrimental problem associated with the application of other nutrients contained in the lagoon effluent. Major interest in this study was to determine the quantity of N and other constituents that could be deposited in Coastal bermudagrass forage without adversely affecting stands or forage quality.

The high N level produced greatest dry matter yields averaging 15,806 kg/ha for the seven-year trial (Table 14,A), but not statistically different from the 14,231 kg/ha produced from the medium rate. Both the high and medium rates produced greater yields compared with the low N rate. Forage height among treatments (Table 15,A) varied among years, but averaged similarly for the seven-year trial (37, 40 and 40 cm, respectively for the low, medium and high rates). The yield data indicate little advantage in dry matter production from applying N above the medium rate.

The potential of bermudagrass as a reservoir for disposal of elements in lagoon effluent is partially dependent on stand persistence when subjected to high seasonal effluent applications (up to 1,716 kg/ha of N, Table 13). No reduction in yields occurred among years through 1976. However, in 1977, annual yields were reduced 29%. This reduction, seen in Table 14,A, is associated with reduced yield from both the medium (reduced 32% compared with 1976) and the high (reduced 48% compared with 1976) N rates. Yields for the low rate actually increased slightly (12%) compared with those in 1976. The differential yield reductions in 1977 are attributed mainly to stand losses that occurred in the medium and high N rate plots during the severe winter of 1976-1977. Appreciable stand losses occurred for all three treatments in replication three. Stand scores were obtained the spring of 1977 (Table 16) and again in early May. Note the high values reported for the medium and high rates and for replication three on both scoring dates. Apparently, plants receiving the medium and high loading rates were more prone to winter injury. Also, the close proximity of the clay subsoil to the surface, as present in replication three, adversely influenced stands during the severe winter. Plots that were thinned, were re-sprigged in April 1977 and had recovered well during the summer.

Seasonal dry matter yields increased in 1978 compared with 1977. Increases occurred mainly for the medium and high rates, but they were still lower than in 1976. The winter of 1977-1978 was not as severe as the previous one, but stand losses were again evident by the spring of 1978. Although some stand thinning occurred in most treatments, major losses occurred in replication three (Table 16, June score). Through re-sprigging, all stands had recovered well and were in good condition entering the 1978-1979 winter (Table 16, December score).

TABLE 14. SEASONAL DRY MATTER YIELDS OF COASTAL BERMUDAGRASS

| Management | Nitrogen rate | Yield, kg/ha | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | Mean |
| A. Irrigated | | | | | | | | | |
| Hay | Low | 11,296[*] | 11,444 | 12,557 | 9,542 | 10,752 | 10,497 | 9,137 | 10,747 |
| | Medium | 14,613 | 14,208 | 16,461 | 15,517 | 10,411 | 12,149 | 16,253 | 14,231 |
| | High | 16,161 | 14,282 | 18,683 | 18,822 | 9,642 | 14,072 | 18,968 | 15,806 |
| | Mean | 14,023 | 13,312 | 15,903 | 14,627 | 10,269 | 12,239 | 14,786 | 13,594 |
| LSD ($P<0.01$): | | | | | | | | | |
| Nitrogen rate (NR) | | 2,909 | | | | | | | |
| Year (Y) | | 1,735 | | | | | | | |
| NR X Y | | 3,004 | | | | | | | |
| B. Non-irrigated | | | | | | | | | |
| Hay | 336 (kg/ha) | -- | 10,343[†] | 9,846 | 5,038 | 7,380 | 7,739 | 8,092 | 8,073 |
| Grazed | 201 (kg/ha) | -- | 7,839 | 8,168 | 6,110 | 5,065 | 6,087 | 7,621 | 6,815 |
| | Mean | -- | 9,091 | 9,007 | 5,574 | 6,123 | 6,913 | 7,857 | 7,444 |

[*] Each value is the mean of three replications summed over all harvests within each year.

[†] Each value is the mean of two replications summed over all harvests within each year.

### TABLE 15. SEASONAL MEAN HEIGHT AT HARVEST

| Management | Nitrogen rate | Year | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | 1979 | Mean |
| | | Height, cm | | | | | | | |
| **A. Irrigated** | | | | | | | | | |
| Hay | Low | 28[*] | 39 | 39 | 34 | 37 | 39 | 40 | 37 |
| | Medium | 40 | 35 | 46 | 45 | 33 | 43 | 40 | 40 |
| | High | 37 | 35 | 41 | 47 | 33 | 42 | 44 | 40 |
| **B. Non-irrigated** | | | | | | | | | |
| Hay | 336 (kg/ha) | -- | 27 | 37 | 28 | 28 | 25 | 26 | 28 |
| Grazed | 201 (kg/ha) | -- | 18[†] | 21 | 27 | 24 | 17 | 20 | 22 |

[*] Each value is the mean of three replications and all harvests within each year.

[†] Each value is the mean of two replications in 1974, 1975, and 1979 and four replications in 1976, 1977, and 1978.

### TABLE 16. AVERAGE STAND SCORES, 1977-1978[*]

| Year | Date | Treatments | | | Replication | | |
|---|---|---|---|---|---|---|---|
| | | Low | Medium | High | 1 | 2 | 3 |
| 1977 | April 18 | 4.3[†] | 8.3 | 10.0 | 6.7[‡] | 6.0 | 10.3 |
| | May 3 | 5.0 | 7.0 | 8.7 | 7.0 | 4.0 | 9.7 |
| 1978 | June 8 | 6.3 | 5.7 | 4.0 | 4.7 | 3.3 | 8.0 |
| | Dec. 13 | 2.3 | 3.3 | 2.3 | 2.0 | 2.7 | 3.3 |

[*] Stand scores: 1 = dense and 10 = sprig every one to 1.2 m.

[†] Values are the mean of three replications.

[‡] Values are the mean of three treatments.

Dry matter yields for the medium and high rates in 1979 were quite good and similar to those prior to 1977. The reduced yield for the low rate is partially, if not totally, attributed to the lack of nitrogen applied in April and May due to the reduced N concentrations in the effluent as previously explained.

These data indicate that bermudagrass stands receiving the medium and high effluent rates were more susceptible to winter injury. However, stand losses could be readily repaired and the stands brought back to previous productivity. Also, the occurrence of heavy soil close to the surface (replication three) was associated with severe stand losses for all treatments. Apparently, deeper sand is more conducive to this practice (replications one and two). The only visible adverse symptoms noted of the forage was a temporary chlorotic condition at the high application rate which developed in the regrowth most Septembers.

Yield from the non-irrigated hay and simulated grazing treatments initiated in 1974 were compared statistically to the same treatments initiated in 1976 (different plot shape) and were found similar. Data from both sets of plots were combined. Except for 1976, no significant yield differences were found (Table 14, B). This is partially associated with the similarity between treatments of forage height at many harvests (Table 15,B). The low yields in 1976 are mainly attributed to the below normal rainfall in July and August (Table 4). The average non-irrigated hay yields (8,073 kg/ha) compares as expected with the irrigated low N rate (10,747 kg/ha). The difference of 2,674 kg/ha approaches a 25% advantage in favor of the irrigated treatment.

## Mineral Concentrations and Quantities Removed in the Forage

A general analyses of variance showed a significant year X N rate interaction for all minerals analyzed. Consequently, an individual year analysis was conducted and when significant N loading rates occurred, the treatment sums of squares were partitioned into linear and quadratic components (Table 17). A significant linear (L) component generally indicates that the concentrations of the particular element continued to increase as loading rates increased. A significant departure from linearity, as indicated by the quadratic (Q) component, generally resulted from a plateauing or lowering of the element concentrations (or yield if applicable) between the medium and high N rates.

In general, effluent applications to achieve the N rates selected resulted in significant changes in P, K, Ca, Mg, $Cl^-$, Mn and Zn concentrations during the majority of years in this study. Also, increased effluent application generally increased the concentrations of all minerals except $Cl^-$ (see N rate mean, Table 17). In this case, concentrations either decreased with increased effluent application or increased between the low and medium rate, then declined. The data indicate that P concentrations could be further increased by higher effluent rates (levels continued to increase from medium to high similarly or greater than from low to medium) while K concentrations appeared to be plateauing. Mg shows a trend similar to K while Mn concentrations behaved as did P.

Concentrations of minerals in the forage for 1978 were higher than those in 1973 for only P and Mn. A general trend was increased concentrations from 1973 to 1975-1976. Thereafter concentrations were similar to those in 1973. Noted exceptions are Mn and Fe.

TABLE 17. WEIGHTED SEASONAL MEAN MINERAL CONCENTRATION OF BERMUDAGRASS FOR IRRIGATED TREATMENTS[†]

| Mineral | Nitrogen rate | Year 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | Mean |
|---|---|---|---|---|---|---|---|---|
| | | | | | % | | | |
| P | Low | 0.18[‡] | 0.26 | 0.29 | 0.41 | 0.34 | 0.30 | 0.30 |
| | Med | 0.21 | 0.28 | 0.32 | 0.38 | 0.36 | 0.34 | 0.31 |
| | High | 0.22 | 0.30 | 0.37 | 0.38 | 0.42 | 0.38 | 0.34 |
| | Mean | 0.20 | 0.28 | 0.33 | 0.39 | 0.37 | 0.34 | |
| | Rate trends[‡] | L, Q | L | L | ns | L, Q | L | |
| K | Low | 1.86 | 2.32 | 1.91 | 2.25 | 2.09 | 1.86 | 2.05 |
| | Med | 2.23 | 2.73 | 2.35 | 2.44 | 2.34 | 2.33 | 2.41 |
| | High | 2.44 | 2.78 | 2.53 | 2.47 | 2.54 | 2.19 | 2.49 |
| | Mean | 2.19 | 2.61 | 2.26 | 2.39 | 2.32 | 2.12 | |
| | Rate trends | L, Q | L, Q | L, Q | ns | L | L, Q | |
| Ca | Low | 0.28 | 0.42 | 0.27 | 0.28 | 0.34 | 0.27 | 0.31 |
| | Med | 0.38 | 0.53 | 0.37 | 0.35 | 0.37 | 0.35 | 0.39 |
| | High | 0.48 | 0.57 | 0.41 | 0.40 | 0.35 | 0.34 | 0.42 |
| | Mean | 0.38 | 0.50 | 0.35 | 0.34 | 0.35 | 0.32 | |
| | Rate trends | L | L, Q | L | L, Q | ns | L, Q | |
| Mg | Low | 0.16 | 0.25 | 0.16 | 0.23 | 0.22 | 0.17 | 0.20 |
| | Med | 0.23 | 0.33 | 0.23 | 0.24 | 0.22 | 0.20 | 0.24 |
| | High | 0.27 | 0.33 | 0.25 | 0.24 | 0.25 | 0.20 | 0.26 |
| | Mean | 0.22 | 0.30 | 0.21 | 0.24 | 0.23 | 0.19 | |
| | Rate trends | L, Q | L, Q | L, Q | ns | ns | L, Q | |
| Cl⁻ | Low | 0.77 | 1.14 | 0.83 | 0.93 | 0.77 | 0.69 | 0.86 |
| | Med | 0.88 | 1.01 | 0.82 | 0.95 | 0.72 | 0.79 | 0.86 |
| | High | 0.63 | 0.87 | 0.65 | 0.81 | 0.66 | 0.70 | 0.72 |
| | Mean | 0.76 | 1.01 | 0.77 | 0.90 | 0.72 | 0.73 | |
| | Rate trends | L, Q | L | L, Q | L | ns | ns | |
| | | | | | ppm | | | |
| Mn | Low | 43 | 46 | 37 | 39 | 60 | 47 | 45 |
| | Med | 57 | 53 | 72 | 63 | 93 | 85 | 70 |
| | High | 72 | 59 | 123 | 91 | 169 | 171 | 114 |
| | Mean | 57 | 53 | 77 | 64 | 107 | 101 | |
| | Rate trends | L | ns | L | L | L | L | |
| Cu | Low | 10 | 10 | 9 | 9 | 7 | 7 | 8 |
| | Med | 14 | 10 | 9 | 8 | 7 | 8 | 9 |
| | High | 14 | 10 | 10 | 8 | 8 | 8 | 10 |
| | Mean | 13 | 10 | 9 | 8 | 7 | 8 | |
| | Rate trends | L, Q | ns | L | ns | L | ns | |

(Continued)

TABLE 17. (continued)

| Mineral | Nitrogen rate | Year 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | Mean |
|---|---|---|---|---|---|---|---|---|
| Zn | Low | 24 | 31 | 26 | 30 | 23 | 29 | 27 |
| | Med | 26 | 35 | 28 | 28 | 22 | 30 | 28 |
| | High | 29 | 34 | 34 | 31 | 29 | 37 | 32 |
| | Mean | 26 | 33 | 29 | 29 | 25 | 32 | |
| | Rate trends | L | ns | L | ns | L, Q | L | |
| Fe | Low | 159 | 124 | 97 | 83 | 97 | 99 | 110 |
| | Med | 244 | 161 | 101 | 89 | 93 | 109 | 133 |
| | High | 255 | 144 | 113 | 109 | 104 | 117 | 141 |
| | Mean | 220 | 143 | 103 | 94 | 98 | 108 | |
| | Rate trends | L, Q | ns | L | L | ns | ns | |
| Na | Low | 189 | 335 | 373 | 265 | 365 | 275 | 300 |
| | Med | 329 | 370 | 483 | 290 | 250 | 335 | 343 |
| | High | 325 | 361 | 465 | 298 | 265 | 309 | 337 |
| | Mean | 281 | 355 | 440 | 284 | 293 | 306 | |
| | Rate trends | L, Q | ns | ns | ns | ns | ns | |

[†] All values are weighed for appropriate plot dry matter yield at each harvest date.

[‡] Values are the mean of three replications and variable harvest dates within each year.

[§] All test for significance were made at $P \leq 0.05$. L designates a significant linear trend among nitrogen rates and Q designates a significant departure from linearity representing a quadratic trend, ns designates not significant.

The mineral concentrations in bermudagrass from the non-irrigated reference plots (Table 18) were generally similar between the hay and simulated grazing treatments. Occasional differences were significant depending on year, for P, K, Ca, $Cl^-$ and Fe. Of major interest is the comparison (visual) of concentrations for the five year mean with those found in the high N rate of the irrigated plots (Table 17). Excess availability of P, K, Ca, Mg, $Cl^-$, Mn, Cu, Zn and Na in the effluent tended to increase concentrations over those normally present (not compared statistically) while Fe concentrations were, in general, suppressed.

The S status of the Coastal bermudagrass hay was examined on a limited basis with analyses being conducted only in 1973 and again in 1978. Concentrations in forage from the June and August harvests in 1973 (Table 19,A) were generally adequate for plant growth being similar to or exceeding the accepted requirement of 0.20% (Bird et al., 1978). However, in 1978, concentrations in the June harvested forage averaged only 0.12, 0.15 and 0.14% for the low, medium and high N rates. August concentrations were higher and appeared adequate. The S concentration in the non-irrigated forage, obtained only in 1978, averaged 0.19% for the hay treatment and 0.15% for the simulated grazing treatment in June, but increased to over 0.20% in the August harvest (Table 19,B).

The N:S ratios were appreciably narrower in the forage harvested in 1973 compared with forage harvested in 1978 (Table 19,A). The ratios in 1973 were narrower than recommended for plant growth (14 to 16:1) while those from the June harvest in 1978 were appreciably wider (23 to 25:1) with the August harvest ratios being satisfactory (12 to 20:1). The ratios in 1973 were satisfactory for ruminant nutrition (10 to 12:1), ranging from 8 to 12:1, but in 1978, generally wider than desired. These data suggest, on the average, some reduction in S concentration between 1973 and 1978.

Nitrate ($NO_3^-$) concentrations were also monitored on a limited basis in 1978. Their concentrations in forage irrigated with the low, medium and high N rates were 0.08%, 0.16% and 0.35%, respectively. The 0.35% for the high-rate N treatment was higher than the 0.3% $NO_3^-$ concentration generally considered toxic (Murphy and Smith, 1967). The results for the low-rate N effluent treatment and the fertilized plots (0.03 - 0.07% $NO_3^-$) are consistent with other reports that show rather low accumulations of $NO_3^-$ in bermudagrass (Hajjati et al., 1972).

Comparison of the range of elements present in the bermudagrass forage with requirements of growing and finishing steers (Table 20) indicate a general adequacy of all elements listed (N, P, K, Ca, Na, $Cl^-$, Mg, Mn, Fe, Cu and Zn). Possible toxic levels were approached only for Fe in the non-irrigated forages. In general, bermudagrass irrigated with swine lagoon effluent should not be detrimental to animal health.

The quantities of minerals removed per unit land area in irrigated Coastal bermudagrass (Table 21) was determined by the product of mineral concentrations and dry matter yield computed on an individual plot basis. Except for $Cl^-$, the higher concentrations of minerals in the high N rate and the associated highest dry matter yields resulted in larger quantities

TABLE 18. WEIGHTED SEASONAL MEAN MINERAL CONCENTRATIONS OF BERMUDAGRASS FOR TOPDRESSED PLOTS[†]

| Mineral | Management | Year | | | | | Mean |
|---|---|---|---|---|---|---|---|
| | | 1974 | 1975 | 1976 | 1977 | 1978 | |
| | | % | | | | | |
| P | Hay | 0.24[‡] | 0.19 | 0.17 | 0.17 | 0.21 | 0.20 |
| | Grazed | 0.23 | 0.17 | 0.15 | 0.15 | 0.21 | 0.18 |
| | Difference[§] | ns | ns | ns | ns | ns | |
| K | Hay | 1.76 | 1.62 | 1.24 | 1.52 | 1.46 | 1.46 |
| | Grazed | 1.59 | 1.31 | 1.43 | 1.36 | 1.20 | 1.38 |
| | Difference | * | ns | ns | ns | ns | |
| Ca | Hay | 0.36 | 0.22 | 0.38 | 0.31 | 0.32 | 0.32 |
| | Grazed | 0.35 | 0.30 | 0.30 | 0.27 | 0.27 | 0.29 |
| | Difference | * | ns | * | ns | ns | |
| Mg | Hay | 0.18 | 0.13 | 0.16 | 0.15 | 0.14 | 0.15 |
| | Grazed | 0.18 | 0.14 | 0.20 | 0.16 | 0.14 | 0.16 |
| | Difference | ns | ns | ns | ns | ns | |
| Cl | Hay | 0.19 | 0.66 | 0.48 | 0.40 | 0.35 | 0.42 |
| | Grazed | 0.23 | 0.48 | 0.42 | 0.34 | 0.32 | 0.38 |
| | Difference | ns | * | * | ns | ns | |
| | | ppm | | | | | |
| Mn | Hay | 75 | 77 | 100 | 72 | 85 | 83 |
| | Grazed | 72 | 75 | 87 | 70 | 79 | 79 |
| | Difference | ns | ns | ns | ns | ns | |
| Cu | Hay | 10 | 1 | 5 | 6 | 8 | 6 |
| | Grazed | 9 | 1 | 7 | 6 | 8 | 7 |
| | Difference | ns | ns | ns | ns | ns | |
| Zn | Hay | 29 | 27 | 26 | 22 | 30 | 26 |
| | Grazed | 27 | 26 | 32 | 23 | 37 | 29 |
| | Difference | ns | ns | ns | ns | ns | |
| Fe | Hay | 418 | 89 | 223 | 242 | 238 | 243 |
| | Grazed | 478 | 346 | 317 | 201 | 361 | 317 |
| | Difference | ns | ns | ns | ns | * | |
| Na | Hay | 234 | 204 | 85 | 112 | 173 | 145 |
| | Grazed | 204 | 155 | 106 | 143 | 180 | 153 |
| | Difference | ns | ns | ns | ns | ns | |

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[†] All values are weighed for appropriate plant dry matter yields at each harvest date.

[‡] Values are the mean of two replications in 1974 and 1975 and four replications in 1976, 1977 and 1978 and variable harvest dates within each year.

[§] All tests for significance were made at $P \leq 0.05$; ns designates not significant and * designates significant.

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TABLE 19. SULPHUR CONCENTRATIONS AND N:S RATIOS, 1973 and 1978

| | S (%) | | | | N:S | | | |
|---|---|---|---|---|---|---|---|---|
| | June | | August | | June | | August | |
| Management | 1973 | 1978 | 1973 | 1978 | 1973 | 1978 | 1973 | 1978 |
| A. Irrigated[†] | | | | | | | | |
| Hay: Low N | 0.20 | 0.12 | 0.22 | 0.20 | 10 | 24 | 8 | 12 |
| Medium N | 0.19 | 0.15 | 0.24 | 0.21 | 12 | 23 | 11 | 13 |
| High N | 0.21 | 0.14 | 0.25 | 0.17 | 12 | 25 | 12 | 20 |
| B. Non-irrigated[‡] | | | | | | | | |
| Hay (336 kg N/ha) | -- | 0.19 | -- | 0.22 | -- | 15 | -- | 17 |
| Grazed (201 kg N/ha) | -- | 0.15 | -- | 0.24 | -- | 16 | -- | 12 |

[†] Each value is the mean of three replications.

[‡] Eavh value is the mean of four replications.

(kg/ha) of minerals harvested in the high N treated forage. N rates generally resulted in significant mineral changes for most years. P, K, Ca, Mg, Cu, and Na showed significant departures from linearity for the majority of the years in this trial. This indicates that loading rates above the high rate used would not result in much increase in minerals removed per unit area. Mn was the only mineral that gave a linear trend each year of the trial indicating that higher rates would result in larger removals per unit area. This also tended to be true for Zn. $Cl^-$ removal per unit area followed trends noted for the concentration data (Table 17). Yields generally increased from the low to the medium N rate, then dropped.

The recovery in the forage of elements applied in the effluent is readily determined by comparing the elemental quantities recovered (Tables 21 and 24) with the quantities applied (Table 13). Using the average for the first six years (1973 through 1978) the low N rate resulted in 72% recovery of the applied N (247 kg/339 kg), the medium rate, 57% and the high rate only 33%. Potassium recoveries were similar, averaging 74, 56 and 32% for the low, medium and high N rates. P, a less mobile mineral, gave respective recoveries in the forage dry matter of 41, 28 and 17%. Most elements applied in the effluent were in excess of potential removal by the forage and were therefore potential pollutants in the surface or ground water.

TABLE 20. ELEMENTAL CONCENTRATIONS IN BERMUDAGRASS COMPARED TO REQUIREMENTS OF STEERS AND POSSIBLE TOXICITY CONCENTRATIONS.

| Item | | N (%) | P (%) | K (%) | Ca (%) | Na (%) | $Cl^-$ (%) | Mg (ppm) | Mn (ppm) | Fe (ppm) | Cu (ppm) | Zn (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I Animal (growing and finishing)[†] | | | | | | | | | | | | |
| A. Requirements: | | 2.00 | 0.2-0.7 | 0.6-0.8 | 0.2-1.0 | 0.06 | 0.06 | 4 | 1-10 | 10 | 4 | 20-30 |
| B. Possible toxicity: | | -- | -- | -- | -- | -- | -- | -- | 150 | 400 | 115 | 900 |
| II Coastal bermudagrass composition | | | | | | | | | | | | |
| A. Irrigated | | | | | | | | | | | | |
| Low N | Range | 1.8-2.9 | 0.18-0.41 | 1.86-2.25 | 0.27-0.42 | 0.02-0.04 | 0.8-1.1 | 1,600-2,300 | 37-60 | 83-159 | 7-10 | 23-30 |
| | Mean | 2.2 | 0.30 | 2.05 | 0.31 | 0.03 | 0.9 | 2,000 | 45 | 110 | 8 | 27 |
| Medium N | Range | 2.3-3.2 | 0.21-0.38 | 2.23-2.73 | 0.35-0.53 | 0.03-0.05 | 0.7-1.0 | 2,000-3,300 | 53-93 | 88-244 | 7-14 | 22-30 |
| | Mean | 2.8 | 0.31 | 2.41 | 0.39 | 0.03 | 0.9 | 2,400 | 70 | 133 | 9 | 28 |
| High N | Range | 2.6-3.2 | 0.22-0.42 | 2.19-2.78 | 0.34-0.57 | 0.03-0.05 | 0.6-0.8 | 2,000-3,300 | 59-171 | 104-255 | 8-14 | 29-37 |
| | Mean | 2.9 | 0.34 | 2.49 | 0.42 | 0.03 | 0.7 | 2,600 | 114 | 141 | 10 | 32 |
| B. Non-irrigated | | | | | | | | | | | | |
| Hay | Range | 1.4-2.6 | 0.17-0.24 | 1.24-1.76 | 0.22-0.38 | 0.01-0.02 | 0.19-0.66 | 1,300-1,800 | 72-100 | 89-418 | 1-10 | 22-30 |
| | Mean | 2.0 | 0.20 | 1.46 | 0.32 | 0.01 | 0.42 | 1,500 | 83 | 243 | 6 | 26 |
| Grazed | Range | 1.9-2.2 | 0.15-0.23 | 1.20-1.59 | 0.27-0.35 | 0.01-0.02 | 0.23-0.48 | 1,400-2,000 | 72-87 | 201-478 | 1-9 | 26-37 |
| (simulated) | Mean | 2.1 | 0.18 | 1.38 | 0.29 | 0.01 | 0.38 | 1,600 | 79 | 317 | 7 | 29 |

[†] Requirements and possible toxicity concentrations taken from "Nutritional Requirements of Domestic Animals," No. 4, Nutritional Requirements of Beef Cattle, revised edition, 1976, National Academy of Science, Washington, D. C.

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TABLE 21. SEASONAL QUANTITIES OF MINERALS REMOVED IN BERMUDAGRASS FOR IRRIGATED TREATMENTS

| Mineral | Nitrogen rate | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | Mean |
|---|---|---|---|---|---|---|---|---|
| | | Kg/ha | | | | | | |
| P | Low | 21[†] | 29 | 36 | 39 | 37 | 31 | 32 |
| | Med | 31 | 40 | 53 | 59 | 37 | 41 | 43 |
| | High | 35 | 43 | 69 | 72 | 40 | 53 | 52 |
| | Mean | 29 | 37 | 53 | 57 | 38 | 42 | |
| | Rate trends | L, Q | L, Q | L, Q | L, Q | ns | L | |
| K | Low | 210 | 266 | 240 | 214 | 220 | 195 | 224 |
| | Med | 334 | 387 | 386 | 379 | 241 | 283 | 335 |
| | High | 394 | 397 | 473 | 465 | 243 | 308 | 380 |
| | Mean | 313 | 350 | 367 | 353 | 235 | 261 | |
| | Rate trends | L, Q | L, Q | L, Q | L, Q | ns | L | |
| Ca | Low | 32 | 48 | 35 | 27 | 36 | 29 | 34 |
| | Med | 56 | 75 | 60 | 54 | 39 | 43 | 54 |
| | High | 77 | 79 | 76 | 75 | 34 | 48 | 65 |
| | Mean | 55 | 67 | 57 | 52 | 36 | 40 | |
| | Rate trends | L | L, Q | L, Q | L, Q | ns | L | |
| Mg | Low | 18 | 28 | 20 | 22 | 23 | 17 | 21 |
| | Med | 34 | 47 | 38 | 37 | 23 | 25 | 34 |
| | High | 44 | 48 | 46 | 45 | 24 | 28 | 39 |
| | Mean | 32 | 41 | 35 | 35 | 23 | 23 | |
| | Rate trends | L | L, Q | L, Q | L, Q | ns | L | |
| $Cl^-$ | Low | 88 | 131 | 104 | 88 | 87 | 73 | 95 |
| | Med | 128 | 143 | 135 | 147 | 75 | 96 | 121 |
| | High | 103 | 124 | 121 | 153 | 63 | 98 | 110 |
| | Mean | 106 | 133 | 120 | 129 | 75 | 89 | |
| | Rate trends | Q | ns | Q | L, Q | ns | ns | |
| Mn | Low | 0.49 | 0.53 | 0.45 | 0.37 | 0.58 | 0.49 | 0.48 |
| | Med | 0.83 | 0.75 | 1.18 | 0.97 | 0.95 | 1.03 | 0.95 |
| | High | 1.17 | 0.84 | 2.30 | 1.70 | 1.61 | 2.40 | 1.67 |
| | Mean | 0.83 | 0.71 | 1.31 | 1.02 | 1.05 | 1.31 | |
| | Rate trends | L | L | L | L | L | L | |
| Cu | Low | 0.11 | 0.11 | 0.10 | 0.08 | 0.07 | 0.08 | 0.09 |
| | Med | 0.21 | 0.15 | 0.15 | 0.12 | 0.08 | 0.09 | 0.13 |
| | High | 0.23 | 0.13 | 0.18 | 0.16 | 0.08 | 0.11 | 0.15 |
| | Mean | 0.19 | 0.13 | 0.15 | 0.12 | 0.08 | 0.09 | |
| | Rate trends | L, Q | L, Q | L, Q | L, Q | ns | L | |

(Continued)

TABLE 21. (Continued)

| Mineral | Nitrogen rate | Year | | | | | | Mean |
|---|---|---|---|---|---|---|---|---|
| | | 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | |
| Zn | Low | 0.27 | 0.36 | 0.32 | 0.28 | 0.25 | 0.30 | 0.30 |
| | Med | 0.37 | 0.49 | 0.46 | 0.43 | 0.22 | 0.37 | 0.39 |
| | High | 0.47 | 0.48 | 0.64 | 0.57 | 0.28 | 0.53 | 0.49 |
| | Mean | 0.37 | 0.45 | 0.48 | 0.43 | 0.26 | 0.40 | |
| | Rate trends | L | L, Q | L | L, Q | ns | L | |
| Fe | Low | 1.80 | 1.41 | 1.21 | 0.69 | 1.04 | 1.04 | 1.22 |
| | Med | 3.55 | 2.30 | 1.66 | 1.38 | 0.97 | 1.32 | 1.86 |
| | High | 4.12 | 2.05 | 2.12 | 2.05 | 1.01 | 1.65 | 2.16 |
| | Mean | 3.16 | 1.92 | 1.66 | 1.37 | 1.01 | 1.34 | |
| | Rate trends | L, Q | Q | L | L | ns | ns | |
| Na | Low | 2.14 | 3.81 | 4.66 | 2.50 | 3.98 | 2.92 | 3.33 |
| | Med | 4.80 | 5.24 | 7.96 | 4.48 | 2.59 | 4.07 | 4.86 |
| | High | 5.25 | 5.13 | 8.69 | 5.60 | 2.53 | 4.35 | 5.26 |
| | Mean | 4.06 | 4.73 | 7.10 | 4.20 | 3.04 | 3.78 | |
| | Rate trends | L, Q | L, Q | L, Q | L, Q | ns | ns | |

[†] Each value is the mean of three replications and summed over all harvests within each year.

[‡] All tests for significance were made at $P \leq 0.05$. L designates a significant linear trend among nitrogen rates and Q designates a significant departure from linearity representing a quadratic trend, ns designates not significant.

The kg/ha of minerals removed in bermudagrass from the non-irrigated plots (Table 22) differed between the hay and simulated grazing treatments for only K for the majority of the years in the study. In two of the five years, P, Mg and Cu showed significant differences between treatments. The quantity (kg/ha) of the various minerals that can potentially be removed in bermudagrass relative to normal removal can be estimated by comparing the quantities from the high N rate in the irrigated plots (Table 21) with those from the reference plots (visual comparisons, Table 22). Total removal in favor of the irrigated treatment ranged from essentially no difference (Fe) to 12.2 times (Na). Most differences in favor of the irrigated, high N rate, were two to four fold.

## Effluent Residue Retained on Forage Surface

When lagoon effluent is sprinkler irrigated, as in this experiment, effluent residue could possibly accumulate on leaf and stem surfaces and perhaps influence plant growth or be a factor in subsequent animal response to the forage. Two experiments were conducted to obtain initial information on washing procedures and these results were used as guidelines for washing of residue from the forage harvested in 1973 and 1975. Procedures and results of these studies are presented in Appendix B.

In general, the results indicated that effluent residue is contained on leaf surfaces, but the concentrations are in general low. Visually, residue accumulations were not a problem nor did they appear to suppress dry matter production. As reported in another section, short-term intake trials with ewes indicated that effluent-irrigated hay will be consumed as well as non-treated hay.

## Nutritive Evaluation

The use of bermudagrass as a reservoir for N and mineral deposition from swine waste incorporated in its some 18,000 kg/ha of dry matter makes it a reasonable option for a swine enterprise. However, its worth as a forage is best realized if it can be used by ruminant animals. Estimates of nutritive value were obtained using IVDMD. IVDMD was significantly altered by N rate for three of the six years in this study with significant departures from linearity in two of the three years (Table 23,A). IVDMD values obtained were rather typical for hay of this maturity and reflect adequate quality for moderate yearling animal growth. Total N was significantly altered by N application in all years. The departure from linearity in all years (Table 23) indicates that higher loading rates would not appreciably increase N concentrations of the forage. Most N levels shown would be adequate (11.3 to 20.3% crude protein) to meet most ruminant N requirements. The increases in the N concentrations is of importance because of the increased use of Coastal bermudagrass meal as a source of protein and vitamins in livestock and poultry feeds. However, it was expected that higher concentrations of N (3 to 4%) would be found in forage from the high loading rate.

### TABLE 22. SEASONAL QUANTITIES OF MINERALS REMOVED IN BERMUDAGRASS FOR TOPDRESSED PLOTS

| Mineral | Management | Year 1974 | 1975 | 1976 | 1977 | 1978 | Mean |
|---|---|---|---|---|---|---|---|
| | | kg/ha | | | | | |
| P | Hay | 25[†] | 18 | 9 | 13 | 16 | 16 |
| | Grazed | 18 | 15 | 10 | 8 | 12 | 13 |
| | Difference[‡] | * | * | ns | ns | ns | |
| K | Hay | 183 | 159 | 63 | 112 | 112 | 126 |
| | Grazed | 124 | 108 | 87 | 92 | 73 | 93 |
| | Difference | * | * | * | ns | ns | |
| Ca | Hay | 37 | 22 | 18 | 22 | 25 | 25 |
| | Grazed | 28 | 25 | 18 | 13 | 17 | 20 |
| | Difference | * | ns | ns | * | ns | |
| Mg | Hay | 18 | 12 | 8 | 11 | 11 | 12 |
| | Grazed | 13 | 12 | 11 | 8 | 8 | 10 |
| | Difference | ns | ns | * | * | ns | |
| Cl | Hay | 20 | 65 | 25 | 31 | 27 | 28 |
| | Grazed | 18 | 39 | 27 | 18 | 19 | 22 |
| | Difference | ns | * | ns | ns | ns | |
| Mn | Hay | 0.8 | 0.7 | 0.5 | 0.5 | 0.7 | 0.6 |
| | Grazed | 0.6 | 0.6 | 0.5 | 0.4 | 0.5 | 0.5 |
| | Difference | ns | ns | ns | ns | ns | |
| Cu | Hay | 0.10 | 0.08 | 0.02 | 0.05 | 0.07 | 0.05 |
| | Grazed | 0.08 | 0.07 | 0.05 | 0.03 | 0.05 | 0.05 |
| | Difference | ns | * | * | ns | ns | |
| Zn | Hay | 0.3 | 0.3 | 0.1 | 0.2 | 0.2 | 0.2 |
| | Grazed | 0.2 | 0.2 | 0.2 | 0.1 | 0.2 | 0.2 |
| | Difference | * | ns | * | ns | ns | |
| Fe | Hay | 4.3 | 0.9 | 1.1 | 1.8 | 1.9 | 1.9 |
| | Grazed | 3.7 | 2.8 | 2.0 | 1.0 | 2.2 | 2.1 |
| | Difference | ns | ns | * | ns | ns | |
| Na | Hay | 2.4 | 2.0 | 0.4 | 0.8 | 1.3 | 1.2 |
| | Grazed | 1.6 | 1.3 | 0.7 | 0.7 | 1.1 | 1.0 |
| | Difference | ns | ns | ns | ns | ns | |

[†] Values are the mean of two replications in 1974 and 1975 and four replications in 1976, 1977 and 1978 and summed over the harvest within each year.

[‡] All tests for significance were made at $P \leq 0.05$; ns designates not significant.

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## TABLE 23. IN VITRO DRY MATTER DISAPPEARANCE (IVDMD) AND TOTAL NITROGEN CONCENTRATIONS[†]

| Management | Nitrogen rate | Year 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | Mean |
|---|---|---|---|---|---|---|---|---|
| | | % | | | | | | |
| A. Irrigated[≠] | | | | (IVDMD) | | | | |
| Hay | Low | 54.5 | 57.5 | 55.0 | 55.2 | 56.0 | 51.3 | 54.9 |
| | Med | 54.2 | 63.3 | 58.2 | 56.0 | 60.0 | 56.5 | 58.0 |
| | High | 57.1 | 63.5 | 61.3 | 56.3 | 60.6 | 58.5 | 59.5 |
| | Rate trends | ns | L, Q | L | ns | ns | L, Q | - |
| | | | | (Total N) | | | | |
| | Low | 1.80 | 2.42 | 2.15 | 2.08 | 2.39 | 2.14 | 2.24 |
| | Med | 2.27 | 3.21 | 2.75 | 2.59 | 2.93 | 2.86 | 2.77 |
| | High | 2.64 | 3.24 | 3.15 | 2.77 | 2.99 | 2.92 | 2.95 |
| | Rate trends | L, Q | L, Q | L, Q | L, Q | L, Q | L, Q | |
| B. Non-irrigated[≢] | | | | (IVDMD) | | | | |
| Hay [‡] | 336 (kg/ha) | -- | 52.7 | 54.6 | 43.4 | 51.4 | 49.8 | 49.3 |
| Grazed[‡] | 201 (kg/ha) | -- | 51.2 | 50.9 | 45.1 | 52.3 | 54.4 | 51.0 |
| | Difference | -- | ns | ns | ns | ns | ns | - |
| | | | | (Total N) | | | | |
| Hay | 336 (kg/ha) | -- | 2.43 | 2.03 | 1.37 | 1.96 | 2.64 | 2.03 |
| Grazed | 201 (kg/ha) | -- | 2.17 | 2.15 | 2.00 | 1.88 | 2.50 | 2.13 |
| | Difference | -- | * | * | * | ns | ns | - |

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[†] All values are weighted for appropriate plot dry matter yield at each harvest date.

[≠] Values are the mean of three replications and variable harvest dates within each year.

[≢] Values are the mean of two replications in 1974 and 1975 and four replications in 1976, 1977 and 1978 and variable harvest dates within each year

[‡] All tests for significance were made at $P \leq 0.05$; L designates a significant linear trend among nitrogen rates and Q designates a significant departure from linearity representing a quadratic trend, ns designates not significant.

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The IVDMD values for the hay and simulated grazed treatments in the reference plots were similar for all years (Table 23,B) and averaged about 8.5 IVDMD units lower than the high N rate of the irrigated plots. This difference is of biological significance as such low IVDMD values border on being adequate only for animal maintenance. N values were significantly higher in the grazed forage in 1974 through 1976. Except for the low concentration in bermudagrass hay in 1976 (1.37% N), N concentrations are adequate to meet most ruminants' needs.

The quantity of digestible dry matter (established by IVDMD) produced/ha is quite high averaging 9,066 kg (Table 24,A) for the high N rate with an experimental high of 11,451 kg/ha in 1975. Nitrogen application resulted in significant linear trends for five of the six years, indicating that higher N rates would yield increased quantities (kg) of digestible dry matter/ha.

The non-irrigated reference treatments (Table 24,B) differed in estimated digestible, dry matter produced in 1974, 1975 and 1976. The hay treatment yielded more in 1974 and 1975 and the simulated grazing treatment more in 1976. The mean kg/ha (3,478) for the two treatments averaged 38% of the high N irrigated treatment (9,066 kg/ha). Total N harvested per ha gave similar results as digestible dry matter. The mean quantity of N harvested in the two treatments (153 kg/ha) averaged about 34% of the N harvested in the high N, irrigated treatment (450 kg/ha).

The possible negative influence of effluent residue on animal dry matter intake was evaluated in a short-term intake trial. Hay intake (Table 25) was not different among the control and the low, medium and high N rates. Although of less interest in this study, a significant breed difference was present with grade Suffolk ewes consuming more hay in relationship to body weight than Dorset ewes (0.020 vs. 0.015 kg ha/kg body weight). There was no visual evidence that lagoon effluent reduced hay palatability. However, the difference in IVDMD and total N between the control hay and the high N rate hay is of sufficient magnitude to expect some difference in dry matter intake (Table 25), although forage digestibility and dry matter intake are not always correlated. This lack of difference in intake could also be interpreted as a negative influence of the residue. This is suggested since the highest quality hay (high N rate) had the highest residue application but the lowest intake (0.016 kg/kg of body wt); however, statistically, the intakes are not different. This trial is not of sufficient length to clarify that point. One can only conclude that the effluent treated hay will be consumed as well as non-treated hay. Further, this experiment provides no information on the extent to which increases in heavy metals and other changes in hay composition would affect animal performance and health.

## TABLE 24. DIGESTIBLE DRY MATTER AND TOTAL N

| Management | Nitrogen rate | Year 1973 | 1974 | 1975 | 1976 | 1977 | 1978 | Mean |
|---|---|---|---|---|---|---|---|---|
| A. Irrigated [†] | | | | | | | | |
| | | Estimated digestible dry matter (kg/ha) | | | | | | |
| Hay | Low | 6164 | 6569 | 6915 | 5285 | 5911 | 5382 | 6038 |
| | Med | 7905 | 8985 | 9581 | 8680 | 6256 | 6860 | 8045 |
| | High | 9221 | 9067 | 11451 | 10590 | 5827 | 8235 | 9066 |
| | Means | 7763 | 8206 | 9317 | 8185 | 5999 | 6825 | |
| | Rate trends [§] | L | L | L | L | ns | L | |
| | | Total N (kg/ha) | | | | | | |
| | Low | 203 | 277 | 271 | 199 | 248 | 225 | 247 |
| | Med | 332 | 455 | 452 | 401 | 305 | 347 | 382 |
| | High | 427 | 462 | 589 | 522 | 288 | 410 | 450 |
| | Means | 321 | 398 | 437 | 374 | 280 | 328 | |
| | Rate trends | L | L | L | L | ns | L | |
| B. Non-irrigated [§] | | | | | | | | |
| | | Estimated digestible dry matter (kg/ha) | | | | | | |
| Hay | 336 (kg/ha) | — | 5454 | 5380 | 2184 | 3784 | 3857 | 3758 |
| Grazed | 201 (kg/ha) | — | 4013 | 4161 | 2751 | 2673 | 3301 | 3198 |
| Difference [‡] | | | * | * | * | ns | ns | |
| | | Total N (kg/ha) | | | | | | |
| Hay | 336 (kg/ha) | -- | 252 | 201 | 69 | 143 | 204 | 174 |
| Grazed | 201 (kg/ha) | -- | 169 | 176 | 121 | 95 | 151 | 133 |
| Difference | | | * | * | * | * | ns | |

[†] Each value is the mean of three replications and summed over all harvests within each year.

[‡] Each value is the mean of two replications in 1974 and 1975 and four replications in 1976, 1977 and 1978.

[§] All tests for significance were made at $P \leq 0.05$. L designates a significant linear trend and ns designates not significant; and * designates significantly different at the 0.05 level of probability.

## TABLE 25. DRY MATTER INTAKE BY SHEEP

| Hay treatment | No. ewes | Kg/head | kg/kg body wt. | Hay characteristics | | | |
|---|---|---|---|---|---|---|---|
| | | | | Dry matter (%) | IVDMD[*] (%) | Crude protein (%) As fed | Crude protein (%) Dry basis |
| Control | 4 | 1.34 | 0.018 | 91.7 | 45.5[†] | 8.2 | 8.9 |
| Effluent treated: | Nitrogen (N) levels | | | | | | |
| Low N | 3 | 1.21 | 0.018 | 91.9 | 51.9 | 10.2 | 11.1 |
| Medium N | 3 | 1.35 | 0.017 | 92.2 | 57.8 | 13.8 | 15.0 |
| High N | 4 | 1.27 | 0.016 | 92.4 | 62.6 | 17.0 | 18.6 |

[*] IVDMD - In vrito dry matter disappearance.

[†] Oven dry basis.

## SOIL CORE ANALYSES[*]

Soil cores were taken 13 times between September 1973 and October 1978 to measure amounts of nutrients in the soil. Analyses of this data included the determination of treatment differences and accumulation with time (over several years).

Generally, if application of a nutrient was greater than crop uptake, an accumulation of the nutrient was expected. However, the accumulation also depended upon movement with soil water flow, interaction with the soil matrix (e.g. fixation, and adsorption), and transformations (especially for N which could be denitrified and lost as a gas). Materials such as $NO_3^-$ and $Cl^-$ which are negative ions move readily with water and would be expected to accumulate only temporarily in the soil matrix when input exceeded losses by crop uptake, soil water movement, and denitrification. Cations such as K and Ca are held by soil particles in varying degrees and would be expected to accumulate in the soil when applied in excess of crop removal. Nutrients which are fixed by the soil system, such as P for this soil (Woodruff and Kamprath, 1965), would be expected to accumulate; however, the measurability of such accumulation depends on the relative success of the sample analysis procedures which are used in detecting the nutrient. Therefore, the amount of soil accumulation for various nutrients was affected by the crop uptake, movement with soil water, interaction with soil matrix, transformations, volatilization, and the ability to detect the material.

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[*] For results presented in this section, the dilute acid used for extraction of P, K, Ca, Mg, Na and Cu was 0.05 $\underline{N}$ HCl + 0.025 $\underline{N}$ $H_2SO_4$. On figures, values at the same depth followed by the same letter are not significantly different at the 5% level of probability.

## Soil $NO_3$-N

Analysis of soil samples collected to a depth of 75 cm in 1973 and 1974 generally show no significant effect of treatment on soil $NO_3$-N so the data are not reported. Soil $NO_3$-N data for subsequent fall sampling dates are shown in Figure 7. The sandy texture of the upper 30 cm of the profile (Table 26) resulted in little $NO_3$-N accumulation in this zone except in 1978. Rainfall during August-October 1978 was only 12 cm as compared to 29, 29, and 44 cm during the same period in 1975, 1976, and 1977 respectively. Consequently less $NO_3$-N was leached out of the upper 30 cm zone in 1978.

Below 30 cm the effect of application rate was evident with significant differences being generally in the order high rate > medium rate = low rate. Since the control treatment was not replicated it cannot be compared statistically with the other treatments.

Each year an accumulation of $NO_3$-N was evident in the subsoil (Figure 7). This accumulation has been noted in soils of the southeastern United States (Boswell and Anderson, 1970, 1964; King and Morris, 1972; Langdale et al., 1979). It is thought to be a result of the weak adsorption of $NO_3^-$ ions in acid subsoils high in Al and Fe oxides (Fiskell and Perkins, 1970; Thomas, 1970) and a result of non-uniform water movement in the subsoil. In well structured soil (in this case the subsoil) the pore size distribution is such that much of the applied water moves through the large pores and therefore does not leach $NO_3$-N out of the small pores (Shaffer et al., 1979; Shuford et al., 1977; Thomas and Phillips, 1979). Figure 8 shows that even after winter rains, appreciable $NO_3$-N was still retained in the subsoil.

## Soil N

Total soil N was significantly affected by treatments only in the 60-90 cm layer where N was slightly higher at the high rate (Figure 9). A trend of high rate > medium rate > low rate (significant at 10 to 20% probability) existed below 90 cm. Using bulk densities shown in Table 26 for the upper 75 cm of the profile and an estimated value of 1.5 for deeper layers the total amount of N to 210 cm was estimated. The control treatment contained 5,220 kg/ha N and the effluent plots contained 4,800, 5,250, and 6,020 kg/ha N for the low, medium, and high rates. Thus, of the approximately 6,800 kg/ha of N applied by the high rate during the six-year period only 6,020-5,220 = 800 kg/ha or 12% remained in the soil. Of this 800 kg, about 500 kg was $NO_3$-N.

## Soil Organic Matter

Soil organic matter was not significantly affected by treatments (Figure 10).

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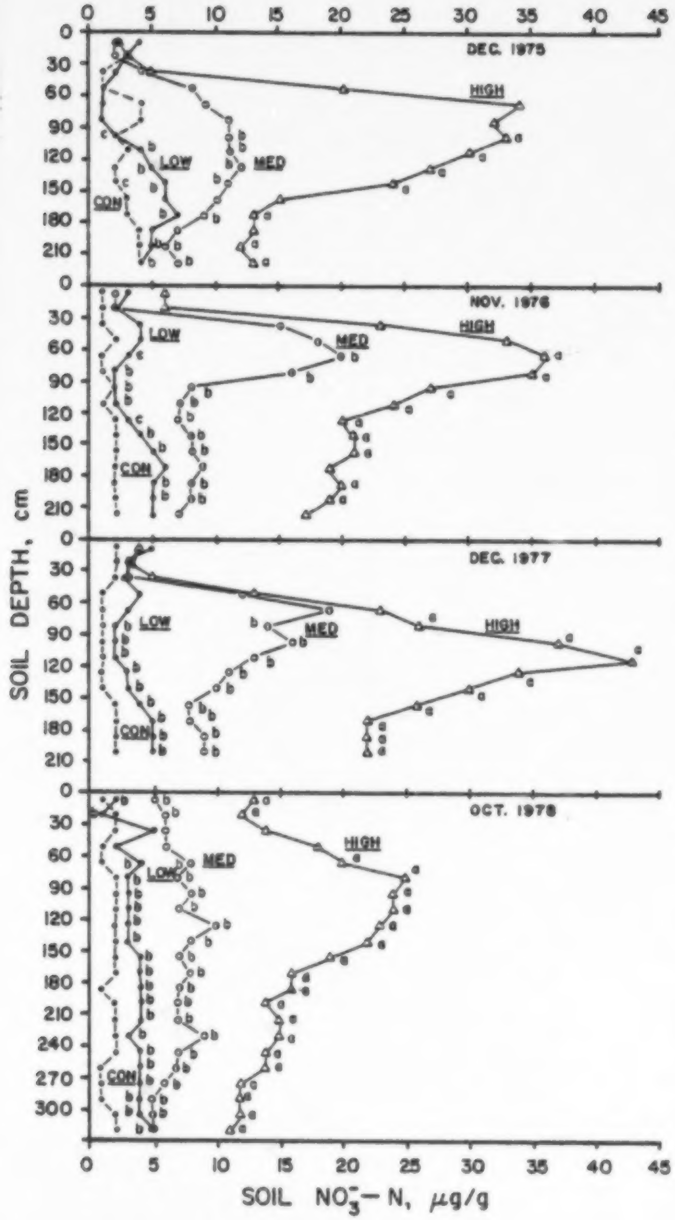

Figure 7. Effect of lagoon effluent irrigation rates on soil $NO_3$-N.

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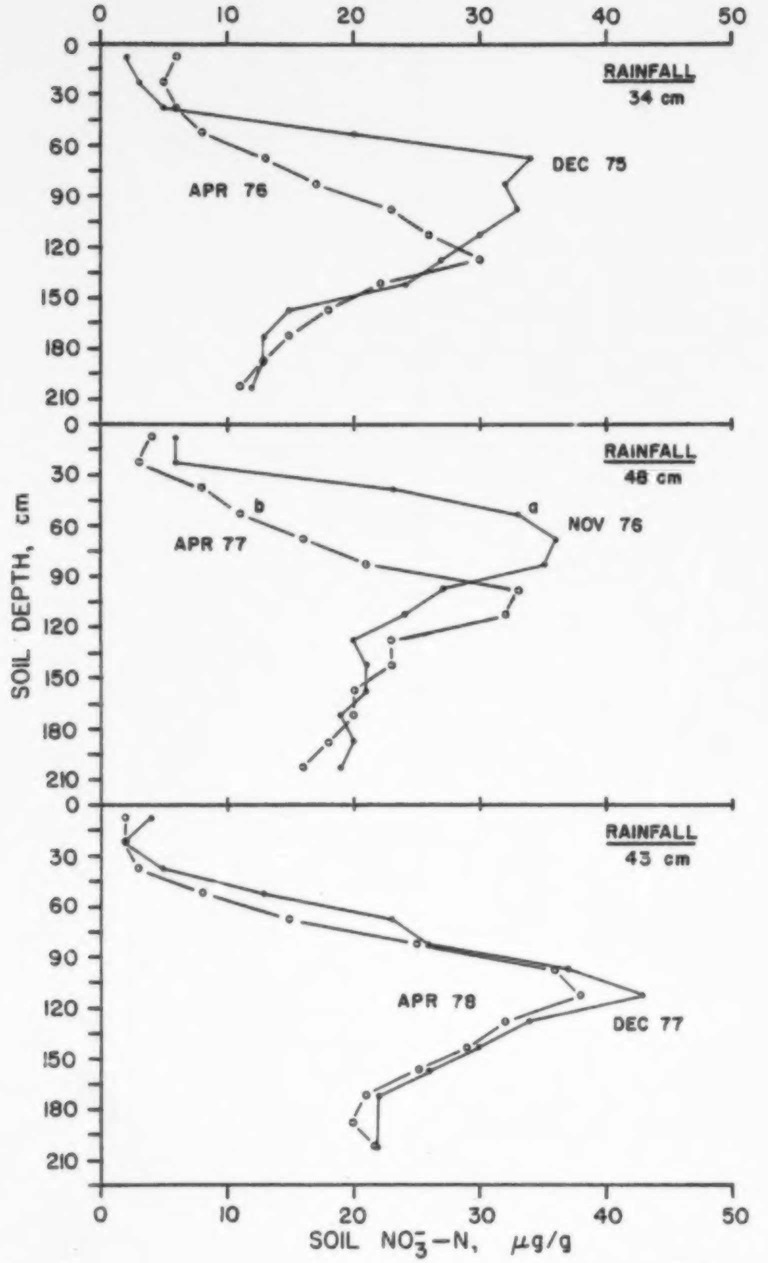

Figure 8. Change in soil $NO_3$-N at the high effluent rate as influenced by winter rainfall.

TABLE 26. SOIL PARTICLE SIZE ANALYSIS AND BULK DENSITY

| Depth | Sand | Silt | Clay | Bulk Density |
|---|---|---|---|---|
| cm | | % | | g/cc |
| 0-7 | 88 | 10 | 2 | 1.63 |
| 7-15 | 87 | 11 | 2 | 1.70 |
| 15-22 | 87 | 10 | 3 | 1.75 |
| 22-30 | 85 | 11 | 4 | 1.85 |
| 30-45 | 81 | 11 | 8 | 1.69 |
| 45-60 | 74 | 10 | 16 | 1.61 |
| 60-75 | 69 | 8 | 23 | 1.55 |
| 75-90 | 61 | 10 | 29 | -- |
| 90-105 | 58 | 9 | 33 | -- |
| 105-120 | 55 | 9 | 36 | -- |
| 120-135 | 61 | 7 | 32 | -- |
| 135-150 | 62 | 7 | 31 | -- |
| 150-165 | 64 | 8 | 28 | -- |
| 165-180 | 66 | 7 | 27 | -- |
| 180-195 | 67 | 5 | 28 | -- |
| 195-210 | 69 | 5 | 26 | -- |

## Soil P

The effect of effluent application rate on concentrations of dilute acid extractable soil P was generally in the order high rate > medium rate = low rate for most of the experimental period (Figure 11). Significant differences existed to a depth of 20 cm through 1977. In 1978 differences were significant in the 30-60 cm layer, indicating a significant downward movement of P. The increase in soil P in the control treatment after 1975 resulted from annual maintenance fertilizer applications to the unirrigated borders where the control samples were taken.

The North Carolina Department of Agriculture (NCDA) uses an index system to rate the fertility level of soils based on soil test results: 0-0-25 ~ low, 25-50 ~ medium, 50-100 ~ high. If the P concentrations in the 0-15 cm soil layer in October 1978 are converted to indexes, all the index values are greater than 100 (45 ppm).

## Soil K

Effluent application rates had little effect on K concentrations in the topsoil but concentrations in the subsoil were significantly increased by increasing application rates (Figure 12). Retention of K below 200 cm was low. K concentrations increased with time in the surface horizon and in the subsoil (Figure 13), but seemed to reach an equilibrium in the 15-60 cm zone. At the October 1978 sampling date K concentrations in the 0-15 cm layer were in the "high" category of the NCDA system for all effluent irrigation rates.

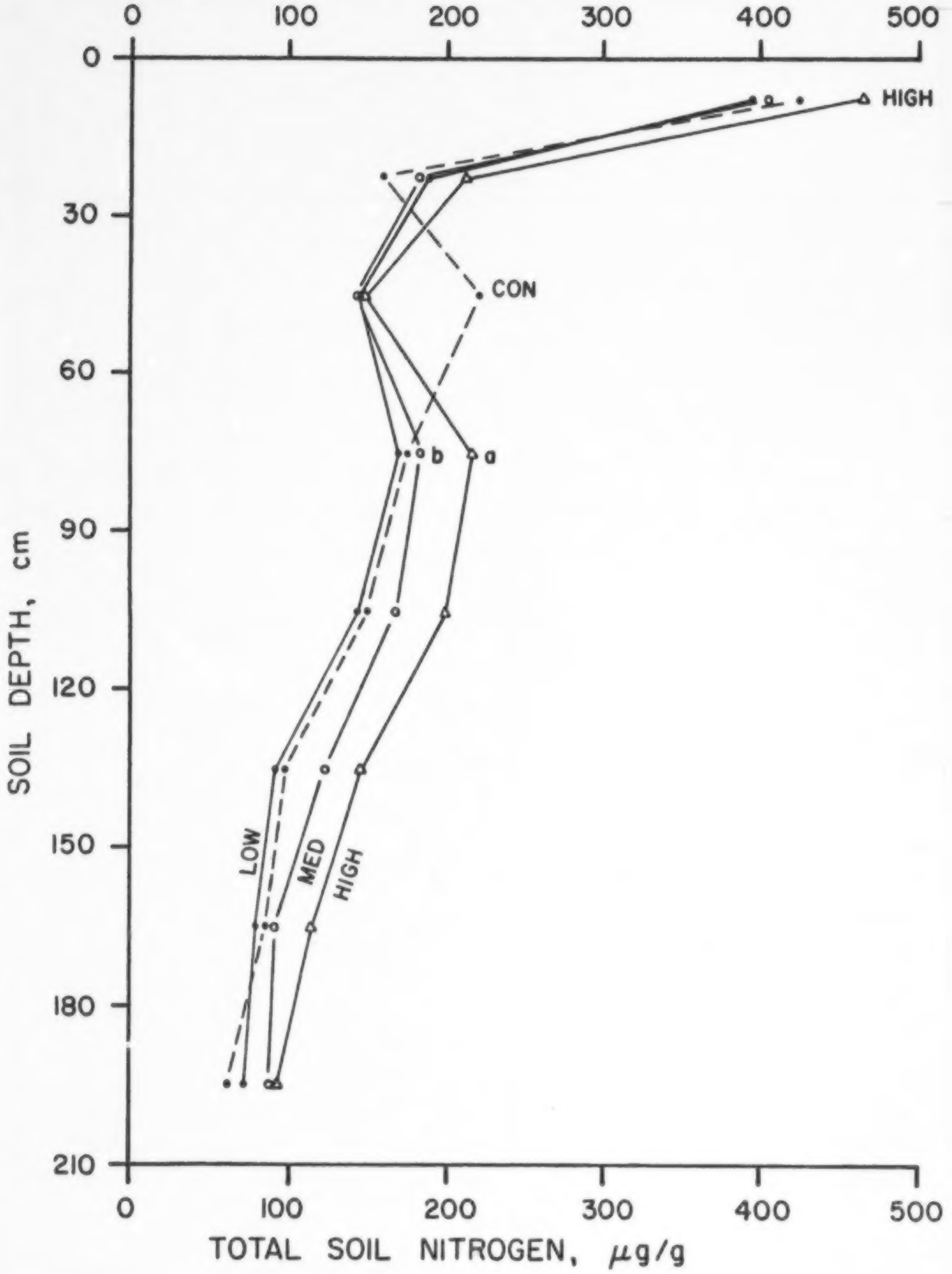

Figure 9. Effect of lagoon effluent irrigation rates on total soil nitrogen.

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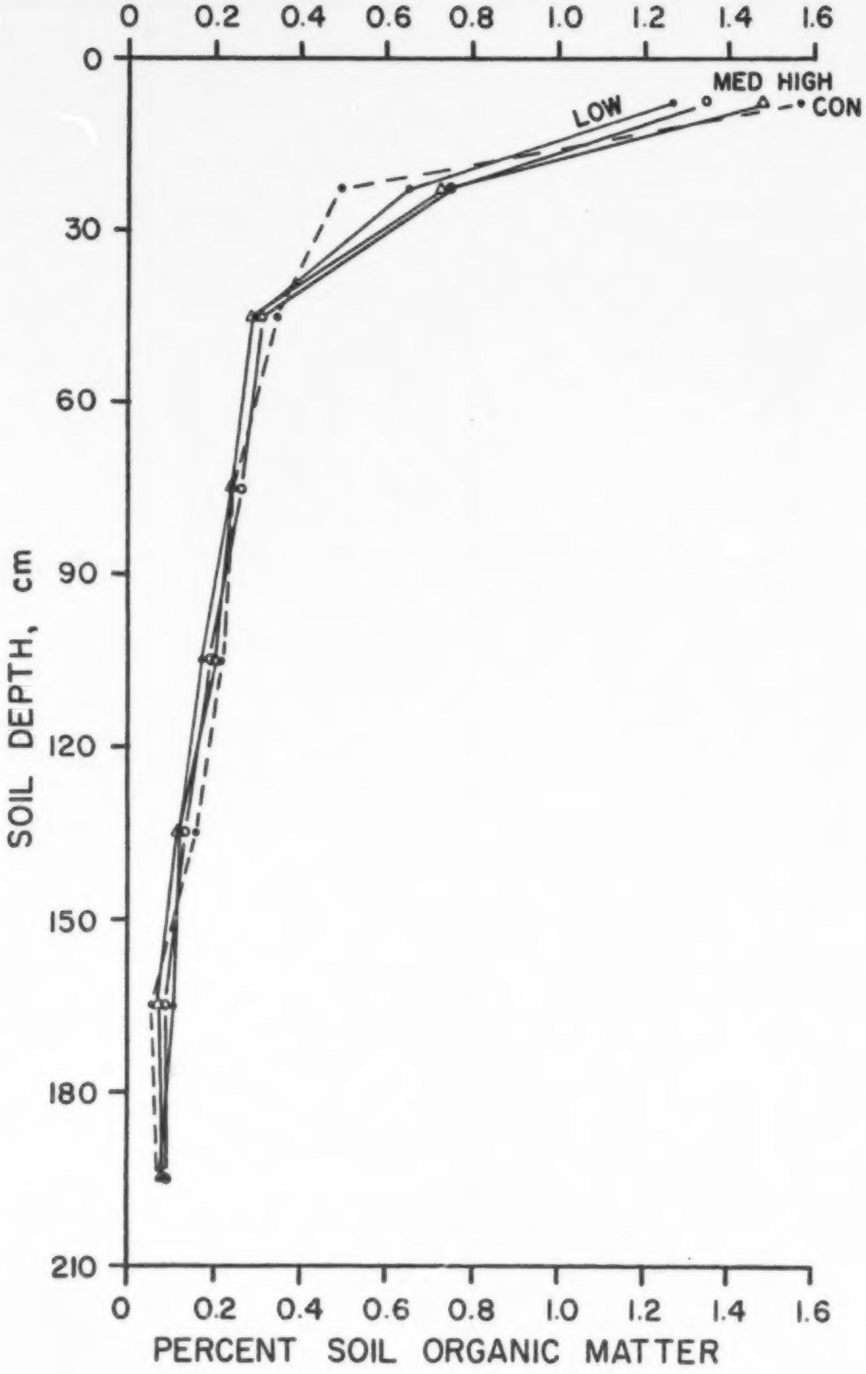

Figure 10. Effect of lagoon effluent irrigation rates on soil organic matter.

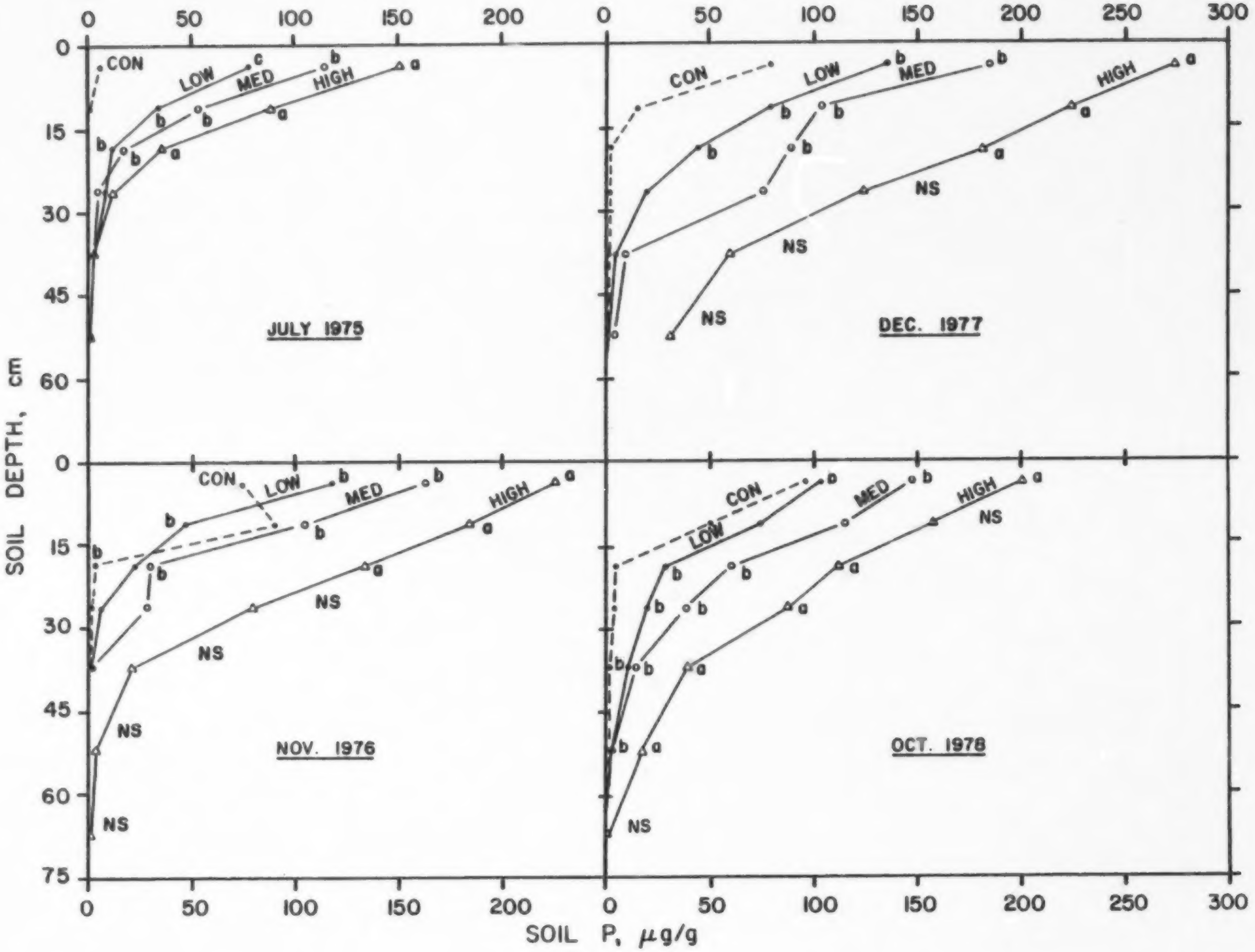

Figure 11. Effect of lagoon effluent irrigation rates on dilute acid extractable soil P.

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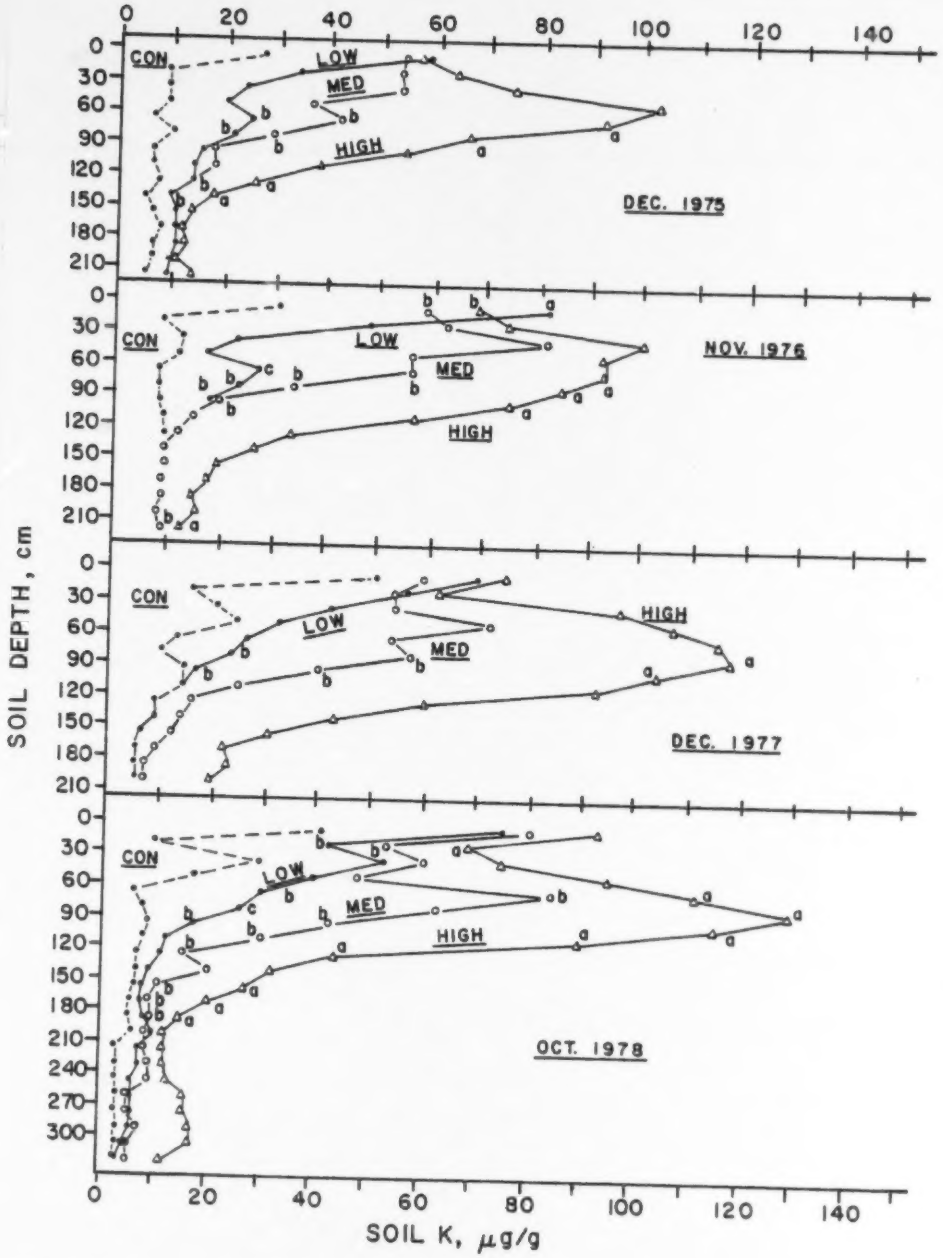

Figure 12. Effect of lagoon effluent irrigation rates on dilute acid extractable soil K.

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## Soil Ca

Effluent rates had little significant effect on soil Ca concentrations during the experimental period so only data from the last sampling date are shown (Figure 14). In the 0-15 cm layer Ca decreased with increasing application rate. Some of the displaced Ca accumulated in the subsoil but a mass balance showed that much of the applied Ca and some native Ca was leached below the 330 cm depth. According to the NCDA soil fertilizer index system Ca concentrations in the 0-15 cm layer were all in the "low" range in October 1978.

## Soil Mg

Soil Mg behaved similarily to Ca in that levels in the topsoil generally decreased with increasing effluent application rate (Figure 15). The Mg displaced from the topsoil moved into the subsoil where concentrations increased with increasing application rate. Time generally had the same effect as rate (Figure 16), i.e. there was a general decline of Mg in the topsoil with time. Subsoil Mg increased to a maximum in 1977 but declined in 1978. According to the NCDA index system, Mg concentrations in the 0-15 cm layer at the last harvest were:

| Application rate | Fertility rating |
|---|---|
| Low | High |
| Medium | Medium |
| High | Low |
| Control | Low |

## Soil Na

Significant effects of treatment on soil Na were few so only December 1975 and October 1978 data are shown (Figure 17). Due to the sandy texture of the upper profile, treatment differences were not significant. However, in the subsoil where the cation exchange capacity (CEC) was higher, differences were significant and were generally in the order high rate > medium rate = low rate. Maximum concentrations for each treatment did not increase appreciably from 1975 to 1978 but it appears that with time Na came into equilibrium with progressively deeper soil layers. The maximum Na concentration was found in the 210-240 cm zone and was 40 ppm or 0.17 meq/100 g soil. This low value of exchangeable Na (approximately 6% Na saturation) and the low soil pH preclude a loss of soil hydraulic conductivity due to Na-induced clay dispersion.

## Soil Zn and Mn

There were no significant effects of treatments on soil Zn or Mn so the data are not presented.

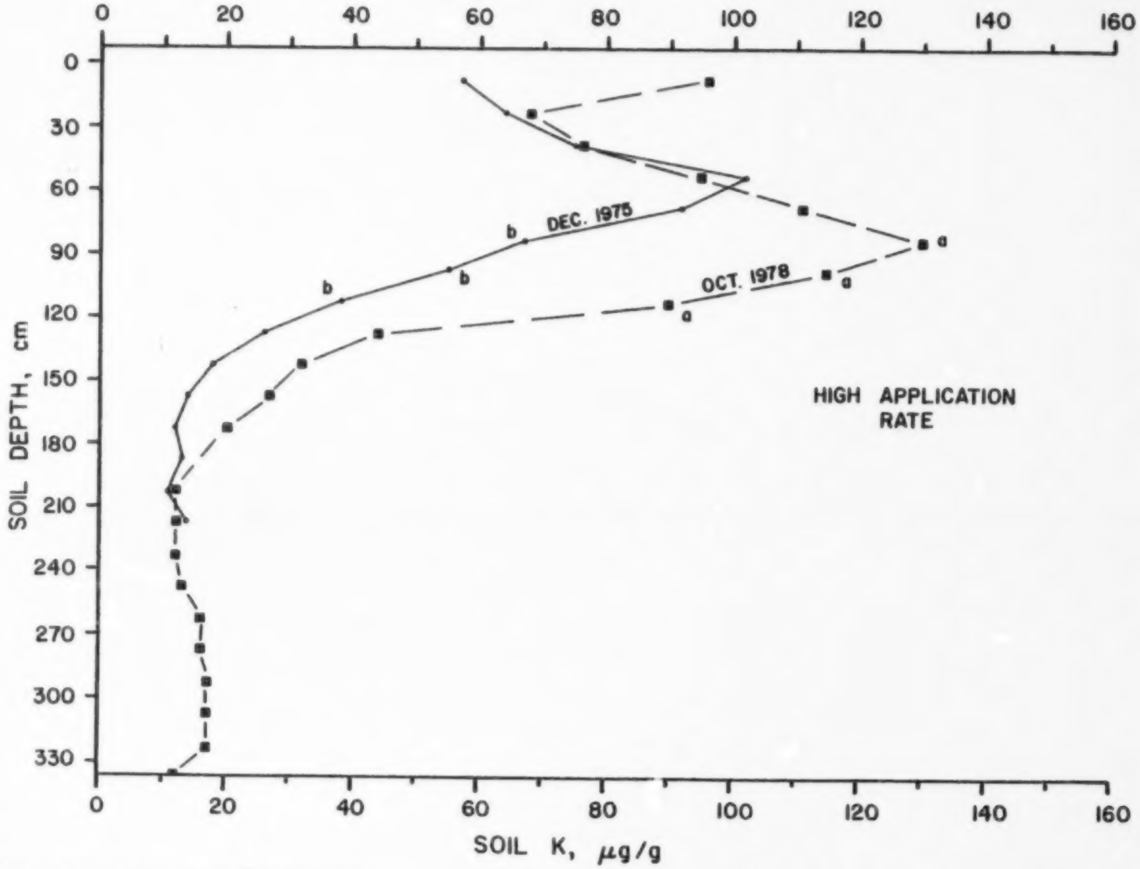

Figure 13. Effect of time change on dilute acid extractable soil K at the high effluent rate.

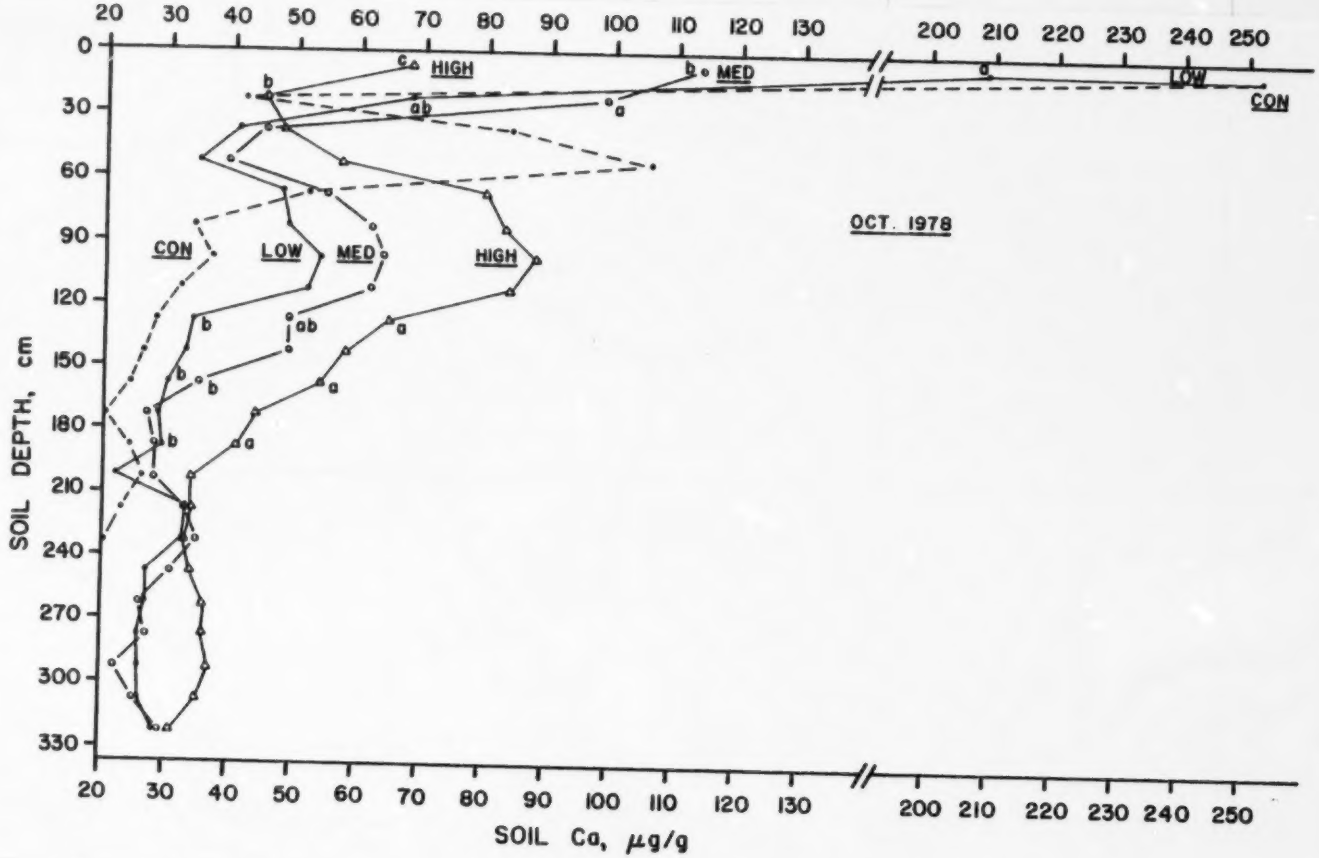

Figure 14. Effect of lagoon effluent irrigation rates on dilute acid extractable soil Ca.

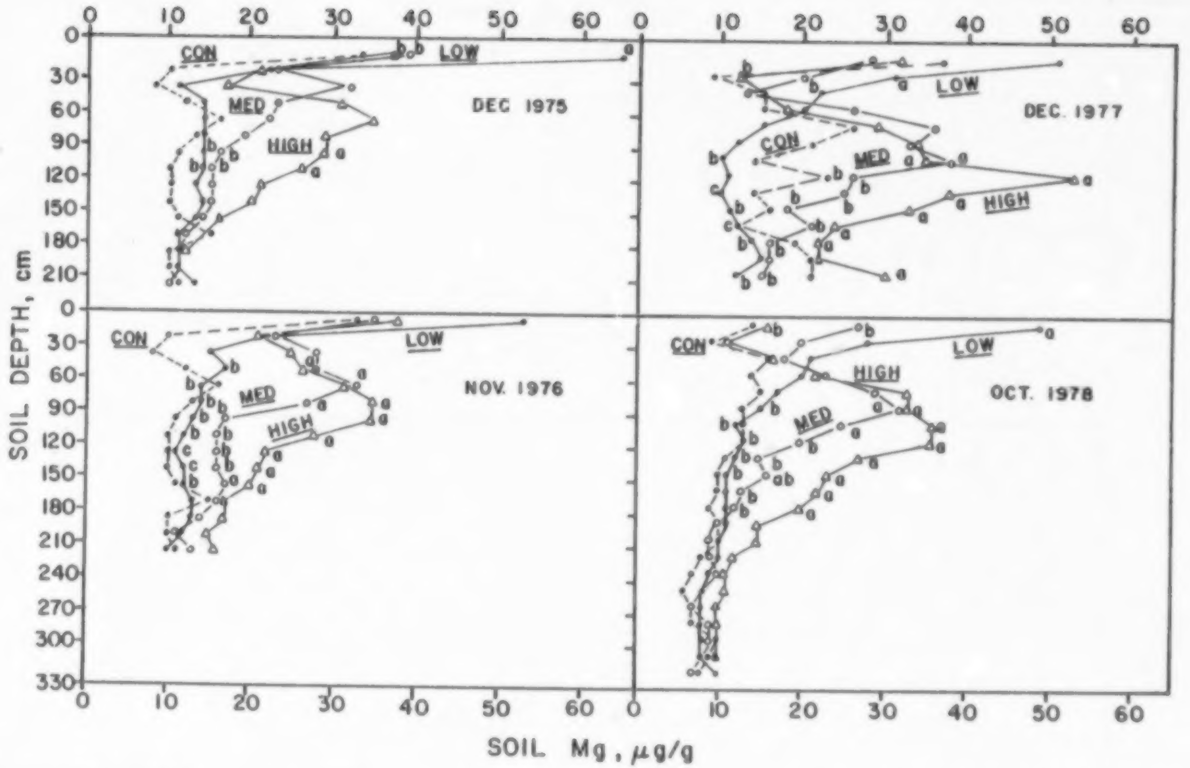

Figure 15. Effect of lagoon effluent irrigation rates on dilute acid extractable soil Mg.

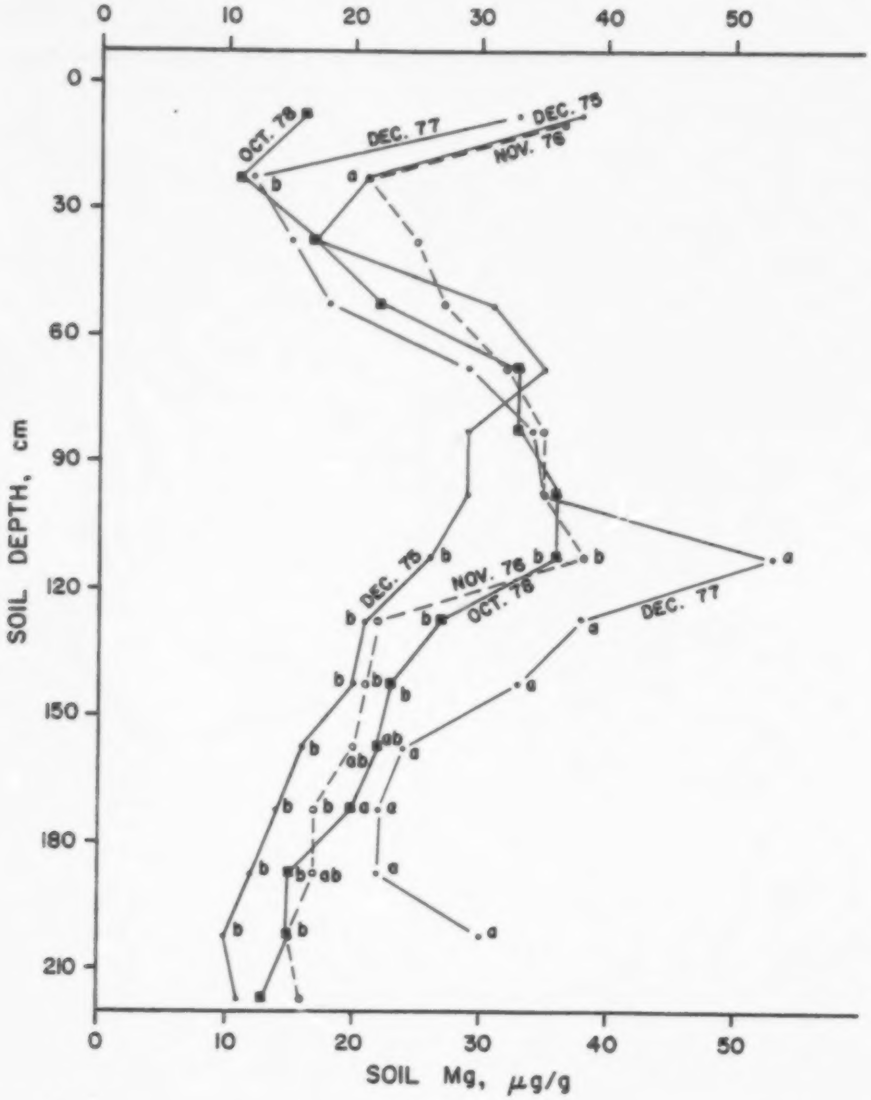

Figure 16. Effect of time on change in dilute acid extractable soil Mg at the high effluent rate.

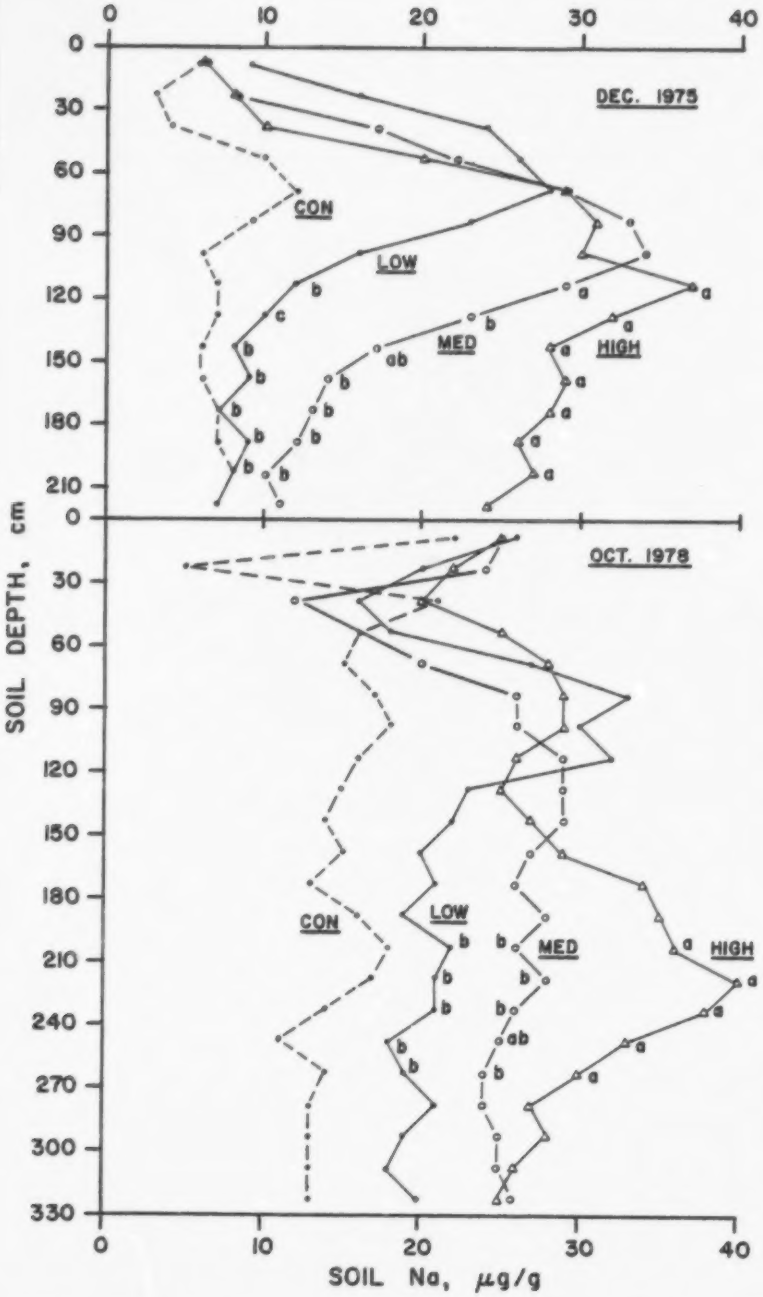

Figure 17. Effect of lagoon effluent irrigation rates on dilute acid extractable soil Na.

## Soil Cu

Cu concentrations were significantly affected by application rates at each sampling date but actual concentrations were low (Figure 18). In November 1976 significant differences among treatments in the 23-30 cm soil layer indicated a downward movement of Cu due to the high application rate. However by October 1978 there was no significant effect of treatment below 15 cm.

## Soil pH

The general effect of treatments on soil pH was a decrease in pH with increasing application rates (Figure 19). In 1977 and 1978 there were large differences between treatments but large variations among replicates of the same treatment resulted in few significant differences. However the trend was still low rate > medium rates > high rate. The decline in pH with increasing application rate is consistent with the loss of Ca and Mg from the surface layer effected by the effluent applications. The effect of time is shown in Figure 20 for the high rate. There was a decline in pH in the top 30 cm from 1975 to 1978 but no significant effect below 30 cm.

## Overall Soil Fertility

The low effluent application rate did not supply enough N for maximum bermudagrass growth and consequently concentrations of residual $NO_3$-N in the soil were low.

The medium rate supplied adequate N for good bermudagrass growth and resulted in only a slight increase in soil $NO_3$-N. However, the high rate supplied an excess of N for crop growth and that excess was reflected in the accumulation of $NO_3$-N in the profile.

Effluent supplied P in excess of bermudagrass needs. Grasses generally require inputs of N and P in a 9:1 N:P ratio for maximum growth. Since the effluent had a N:P ratio of 4.4:1, application rates based on N requirements supplied twice the amount of P required by the grass. Continual application of excess P could cause nutrient imbalance problems (e.g. reduced Fe uptake) but none were noted during the experiment.

K levels were maintained within the "high" fertility range but effluent irrigation decreased Ca and Mg levels in the topsoil. One reason for the decline was the ratio at which effluent supplied cations. Listed below are the major cations applied by the effluent. The data are presented as the ratio of equivalent weights applied with all data normalized to Ca.

| $Ca^{++}$ | $Mg^{++}$ | $Na^+$ | $K^+$ | $NH_4^+$ |
|---|---|---|---|---|
| 1.0 | 1.2 | 2.1 | 2.1 | 6.0 |

It is evident that $Na^+$, $K^+$ and especially $NH_4^+$ would compete strongly for cation exchange sites and result in a displacement of Ca and Mg. The $NH_4^+$ ion has another effect on Ca and Mg in that during microbial transformation of

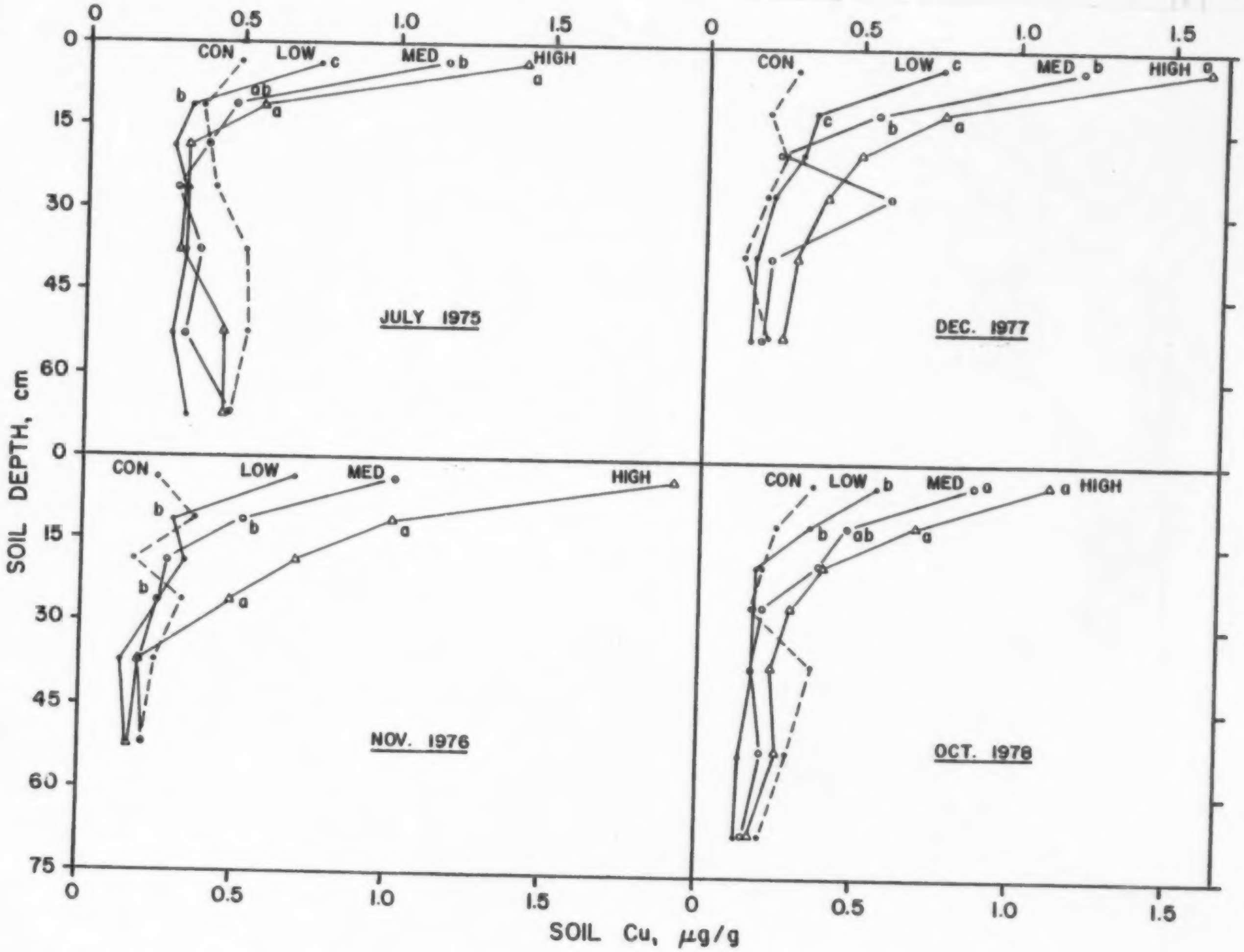

Figure 18. Effect of lagoon effluent irrigation rates on dilute acid extractable soil Cu.

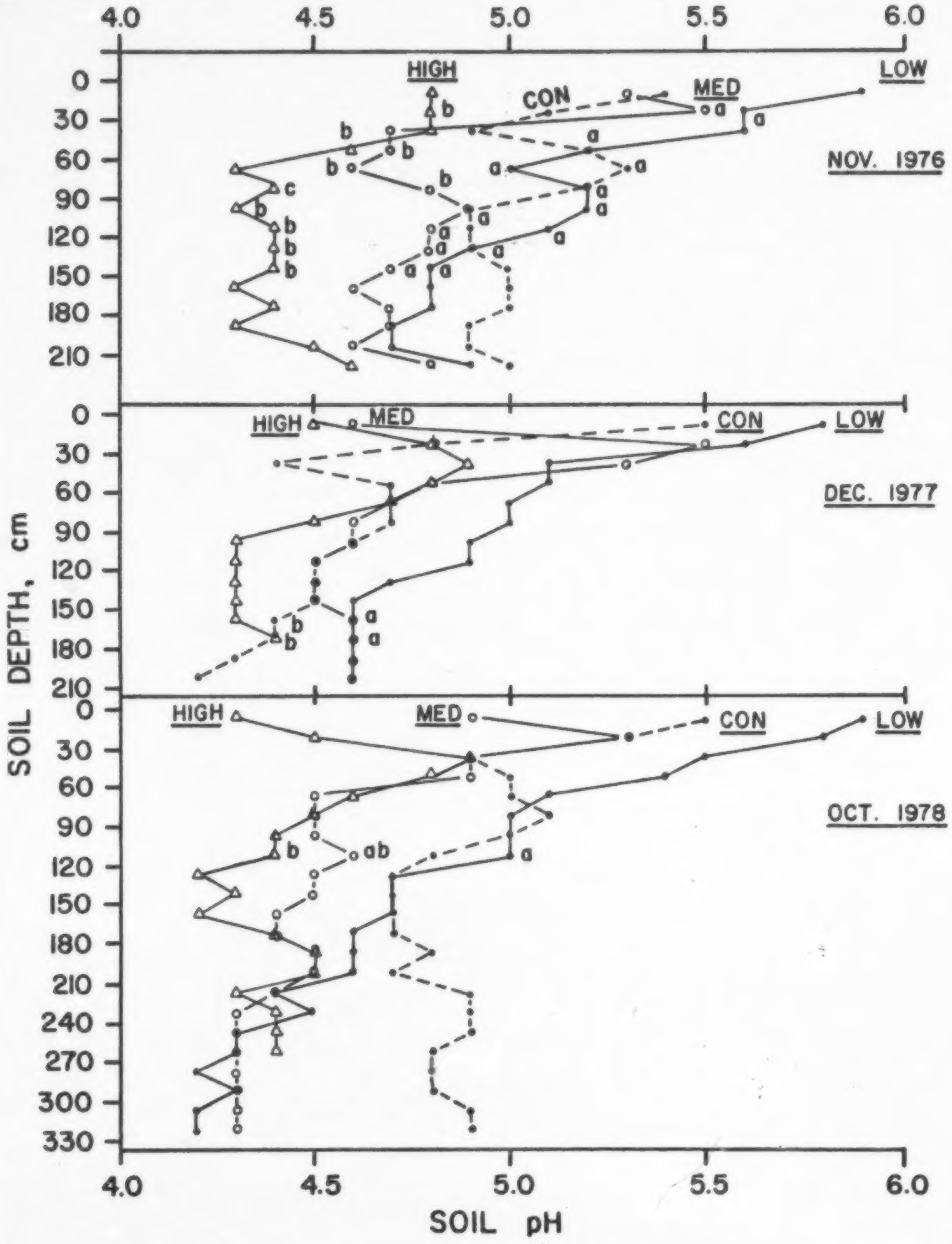

Figure 19. Effect of lagoon effluent irrigation rates on soil pH.

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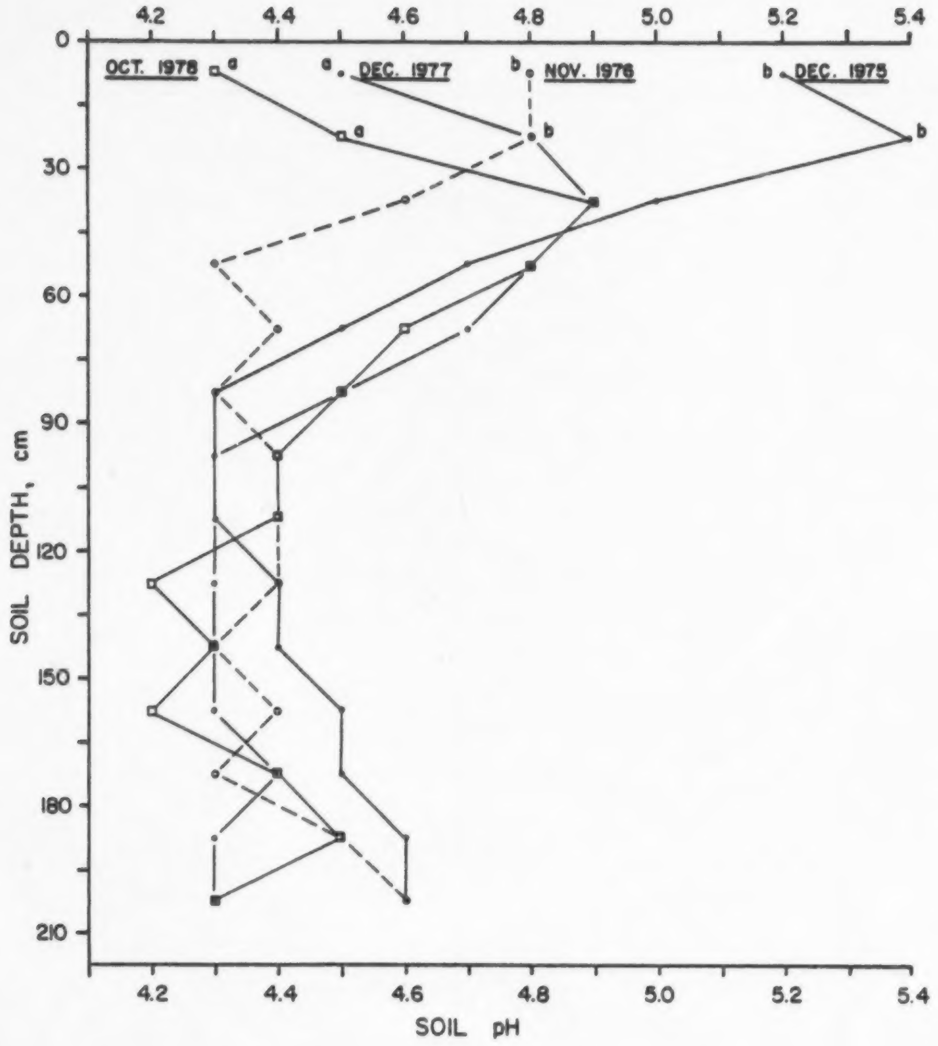

Figure 20. Effect of time change on soil pH at the high effluent rate.

$NH_4^+$ to $NO_3^-$, four $H^+$ ions are released and the soil pH is reduced. This reduction increases competition of Al and H for exchange sites and thus promotes displacement of Ca and Mg.

The loss of Mg and Ca from the topsoil and the concomitant reduction in pH can be counteracted by periodic additions of dolomitic limestone to the soil.

Effluent applications had little or no effect on soil Cu, Zn, and Mn so deficiencies or toxicities of these elements would not be a problem on effluent irrigation fields.

## SURFACE RUNOFF VOLUMES

Surface runoff collection started in April 1973 and ended February 1979. Surface runoff from the nine irrigated plots was collected from a subplot one-eighth the total plot area, except after June 1977 runoff from Replication or Block 2 (plots 4,5, and 6) was collected from the total plot area. The original four fertilized or topdressed plots which simulated pasture and hay treatments had the same area as the runoff subplots of the irrigated plots, but they were longer and more narrow. Four fertilized plots (plots 100, 110, 120 and 130) which were the same shape as the runoff subplots of the irrigated plots were added in October 1975. Changes in collection methods and plot border materials during the period of runoff collection were discussed in the "Experimental Procedures" section. The most significant change which likely affected runoff was the changing of the runoff collection area of plots 4, 5 and 6 from one-eighth the plot area to the total plot area. However, any effect of this change was not evident and thus the runoff analyses were normally by calendar-year periods without regard to any changes during the year.

Runoff collection for each plot was limited to the 208 l capacity of the collection barrel (1.99 cm runoff from the subplot) except that tipping-bucket flow-measuring devices were used on plots 4, 5, and 6 after June 1977 and these had no limitation on flow measurement. The 208 l barrels overflowed a few times during the experimental period because of large runoff amounts. Overflow occurred only during 1975 on Blocks 1 and 2. Plots in Block 3 (plots 7, 8 and 9) had overflow during four years and the topdressed plots had overflow during two years. Consequently, to better compare runoff volumes and to calculate mass transport of nutrients in runoff, the amount of rainfall runoff listed for events when the collection barrel overflowed was adjusted by estimating runoff using the SCS curve-number method (US SCS, 1964). To predict runoff with this method, the plots were considered to be pasture in good hydrologic condition with plots 1-6 in hydrologic soil group B and the other plots in hydrologic soil group C because of less depth to the B horizon compared to plots 1-6. The growing season was taken as May through October. This runoff adjustment method resulted in runoff predictions which were reasonable, but the prediction accuracy could not be evaluated. Annual runoff values which included events which were adjusted for overflow are indicated in the tables for runoff.

Surface runoff was characterized by three different categories: (1) irrigation runoff, (2) irrigation-rainfall mixed runoff, and (3) rainfall runoff. Irrigation normally occurred during the night and if rainfall occurred before samples were collected the next day, then the runoff was designated as irrigation-rainfall mixed runoff. Because of possible direct runoff on or near the gutter collection device and the contamination of runoff from insects and organic materials which could get into the collection gutters between runoff events or gutter cleanings, very small events were neglected in the runoff analyses. The minimum size runoff event included for irrigation or irrigation-rainfall mixed runoff was 0.01 cm, while for rainfall runoff only events of 0.05 cm and greater were included.

## Irrigation Runoff

Irrigation runoff occurred frequently on some plots during the first two years (1973 and 1974). A listing of all irrigation runoff events is in Table D-1. When significant irrigation runoff occurred, rainfall in the two days previous to irrigation was usually 2 cm or more. Annual amounts of irrigation runoff in cm of runoff and as percent of irrigation volume applied are presented in Table 27. Annual rainfall and irrigation amounts are given in Table 28. Runoff as percent of irrigation volume applied was usually less than 1% and seldom exceeded 5%. The average percent runoff for 1974-78 was greater than 1% only for plots 4 and 8. It seemed that better forage stand establishment after the first year reduced irrigation runoff.

TABLE 27. ANNUAL IRRIGATION RUNOFF

| | Plot irrigation runoff, cm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | High application plots | | | Medium application plots | | | Low application plots | | |
| Year | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 |
| 1973 | 2.80 | 2.63 | 2.59 | 0.72 | 0.22 | 1.56 | 0.32 | | 0.10 |
| 1974 | 0.42 | 2.95 | 0.89 | 0.05 | 0.09 | | 0.24 | | 0.08 |
| 1975 | 0.36 | >0.97* | 0.03 | | 0.01 | 0.19 | | | >0.81* |
| 1976 | 0.12 | 0.34 | 0.34 | | | | | | 0.84 |
| 1977 | | 0.16 | | | 0.09 | | | | |
| 1978 | | | 0.12 | | 0.06 | 0.07 | | 0.01 | 0.29 |
| Total | 3.70 | >7.05 | 3.97 | 0.77 | 0.47 | 1.82 | 0.56 | 0.01 | >2.12 |
| | Percent of irrigation applied | | | | | | | | |
| 1973 | 5.1 | 4.8 | 4.7 | 2.6 | 0.8 | 5.7 | 2.3 | 0.0 | 0.7 |
| 1974 | 0.7 | 4.8 | 1.5 | 0.2 | 0.3 | 0.0 | 1.6 | 0.0 | 0.5 |
| 1975 | 0.6 | >1.7* | 0.1 | 0.0 | 0.0 | 0.7 | 0.0 | 0.0 | >5.7* |
| 1976 | 0.2 | 0.7 | 0.0 | 0.0 | 0.0 | 0.5 | 0.0 | 0.0 | 5.5 |
| 1977 | 0.0 | 0.4 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1978 | 0.0 | 0.0 | 0.2 | 0.0 | 0.3 | 0.3 | 0.0 | 0.1 | 3.0 |
| Average | 1.1 | >2.1 | 1.1 | 0.5 | 0.3 | 1.2 | 0.6 | 0.0 | >2.6 |
| 1974-78 | 0.3 | >1.5 | 0.4 | 0.0 | 0.2 | 0.3 | 0.3 | 0.0 | >2.9 |

*Includes event(s) where collection barrel overflowed. No adjustments made for overflow.

TABLE 28. ANNUAL RAINFALL AND IRRIGATION, 1973-1978*

| Year | Rainfall, cm | Irrigation, cm | | | Irrigation plus rainfall, cm | | |
|---|---|---|---|---|---|---|---|
| | | Low | Med | High | Low | Med | High |
| 1973 | 111.5 | 13.7 | 27.4 | 54.8 | 125.2 | 138.9 | 166.3 |
| 1974 | 117.9 | 15.2 | 30.4 | 60.8 | 133.1 | 148.3 | 178.7 |
| 1975 | 136.9 | 14.3 | 28.6 | 57.2 | 151.2 | 165.5 | 194.1 |
| 1976 | 98.0 | 14.9 | 29.7 | 52.8 | 112.9 | 127.7 | 150.8 |
| 1977 | 119.9 | 14.0 | 23.1 | 47.5 | 133.9 | 143.0 | 167.4 |
| 1978 | 110.1 | 10.4 | 24.0 | 49.2 | 120.5 | 134.1 | 159.3 |
| Mean | 115.7 | 13.8 | 27.2 | 53.7 | 129.5 | 142.9 | 169.4 |

*All the irrigation normally occurred during the period April - September. Rainfall for this period averaged 60.5 cm for the six years.

Any runoff associated with irrigation would have high concentrations of nutrients, organics and microorganisms and should be avoided when the runoff could reach a stream or pond. Irrigation runoff occurred in this project mainly because of the schedule of normally irrigating weekly without regard to previous or predicted rainfall. Irrigation rates matched to soil infiltration rates and avoiding irrigation when the soil is already moist should eliminate irrigation runoff. Also, a buffer zone or infiltration area placed downslope of the irrigated area should be effective in reducing pollution impact from irrigation runoff.

### Irrigation-Rainfall Mixed Runoff

When rainfall occurred during irrigation, or immediately after irrigation before the runoff samples were collected, the runoff typically had much higher concentrations than rainfall runoff which occurred several hours after irrigation. The relative amounts of runoff due to irrigation and to rainfall could not be determined in these cases; thus, mixed runoff was characterized separately from rainfall runoff and irrigation runoff. The number of mixed runoff events totaled between two and nine for the various irrigated plots for the six-year period (Table D-2). Runoff amounts of 0.05 cm or more were almost always associated with rainfall of 1 cm or greater. The runoff collection barrels overflowed once with mixed runoff on plots 7 and 8, and three times on plot 9 during the six-year period, but the volumes were not adjusted for overflow. Except for these few times when barrel overflows occurred, the annual amount of mixed runoff was usually less than 1 cm on all plots (Table 29). Runoff events less than 0.01 cm were not included in summaries.

TABLE 29. ANNUAL RAINFALL-IRRIGATION MIXED RUNOFF

| Year | Plot runoff, cm<br>High application plots<br>1 | <br><br>4 | <br><br>7 | <br>Medium application plots<br>3 | <br><br>5 | <br><br>9 | <br>Low application plots<br>2 | <br><br>6 | <br><br>8 |
|---|---|---|---|---|---|---|---|---|---|
| 1973 | 0.38 | 0.02 | 0.96 | 0.05 | | 0.40 | 0.06 | | 0.43 |
| 1974 | 0.82 | 1.40 | 2.09 | 0.46 | 0.31 | >2.16* | 0.58 | | 1.46 |
| 1975 | 0.09 | 0.30 | | | 0.10 | 0.04 | | | |
| 1976 | 0.08 | | 1.10 | 0.01 | | 0.01 | | 0.03 | |
| 1977 | 0.39 | 0.10 | | | 0.10 | | | | 0.01 |
| 1978 | 0.74 | 0.14 | >1.99* | 0.03 | 0.04 | >3.98* | 0.05 | 0.11 | >1.99* |
| Total | 2.50 | 1.96 | >6.14 | 0.55 | 0.55 | >6.59 | 0.69 | 0.14 | >3.89 |

*Includes event(s) where collection barrel overflowed. No adjustments made for overflow.

## Rainfall Runoff and Total Runoff

The annual amounts of the three types of runoff and their annual totals are presented in Table 30. Total annual runoff volumes for plots 1-6 were less than 10 cm each year except for plot 1 in 1973 and plot 4 in 1973 and 1974 when runoff was slightly greater than 10 cm. During the last three years (1976-1978), annual runoff volumes from plots 1-6 were usually less than 1 cm. However, annual runoff volumes from Block 3 (plots 7, 8, and 9) were usually between 10 cm and 20 cm for all years. Block 3 had 18 to 25 cm less topsoil above the less permeable B horizon than Blocks 1 and 2, and because of less storage volume for water in the A horizon the plots in Block 3 had more surface runoff. Thus, the use of the random block design should have increased the precision of the experiment compared to a completely random design. However, the problem of error heterogeneity may also have existed between blocks.

Annual total runoff averaged 1 to 3% of annual rainfall plus irrigation for Blocks 1 and 2, and about 10% for Block 3 for the period 1973-1978 (Table 31). Runoff was usually highest the first two years. Any reduction of runoff with time was likely due to better forage establishment and better stabilization of soil around plot borders and runoff collection devices, instead of any effects of the lagoon effluent on soil physical properties. Addition of animal manures to soil has been reported to increase soil-water infiltration, but this effect was mainly due to addition of organic matter. With lagoon effluent, addition of organic matter is relatively low and likely exerts little influence on soil physical properties.

The fertilized or topdressed plots had a soil profile similar to Block 3. Thus, these non-irrigated plots had annual runoff volumes similar to Block 3. Runoff measurement commenced November 1974 for plots 10-13 and October 1975 for plots 100, 110, 120, and 130. Annual runoff from the topdressed plots for 1975-1978 was usually less than 10% of annual rainfall (Table 32).

## TABLE 30. ANNUAL RUNOFF FOR ALL TYPES OF RUNOFF

| | | Runoff, cm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | High | | | Medium | | | Low | | |
| Year | Type of runoff | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 |
| 1973 | R | 8.88 | 7.89 | 12.47 | 5.68 | 4.43 | 10.45 | 8.28 | 1.26 | 10.28 |
| | R + I | 0.38 | 0.02 | 0.96 | 0.05 | | 0.40 | 0.06 | | 0.43 |
| | I | 2.80 | 2.63 | 2.59 | 0.72 | 0.22 | 1.56 | 0.32 | | 0.10 |
| | Total | 12.06 | 10.54 | 16.02 | 6.45 | 4.65 | 12.41 | 8.66 | 1.26 | 10.81 |
| 1974 | R | 5.20 | 6.64 | 14.79 | 3.24 | 4.01 | 12.89 | 4.78 | 2.17 | 13.74 |
| | R + I | 0.82 | 1.40 | 2.09 | 0.46 | 0.31 | 2.16* | 0.58 | | 1.46 |
| | I | 0.42 | 2.95 | 0.89 | 0.05 | 0.09 | | 0.24 | | 0.08 |
| | Total | 6.44 | 10.99 | 17.77 | 3.75 | 4.41 | 15.05 | 5.60 | 2.17 | 15.28 |
| 1975 | R | 4.31* | 5.67* | 16.04* | 3.19* | 3.79* | 12.53* | 3.86* | 3.84* | 16.29* |
| | R + I | 0.09 | 0.30 | | | 0.10 | 0.04 | | | |
| | I | 0.36 | 0.97* | 0.03 | | 0.01 | 0.19 | | | 0.81* |
| | Total | 4.76 | 6.94 | 16.07 | 3.19 | 3.90 | 12.76 | 3.86 | 3.84 | 17.10 |
| 1976 | R | | | 8.85* | | | 5.47* | 0.11 | | 7.12* |
| | R + I | 0.08 | | 1.10 | 0.01 | | 0.01 | | 0.03 | |
| | I | 0.12 | 0.34 | 0.34 | | | | | | 0.84 |
| | Total | 0.20 | 0.34 | 10.29 | 0.01 | 0.0 | 5.48 | 0.11 | 0.03 | 7.96 |
| 1977 | R | 0.06 | 1.22 | 12.05* | | 0.53 | 11.58* | | 0.59 | 11.92* |
| | R + I | 0.39 | 0.10 | | | 0.10 | | | | 0.01 |
| | I | | 0.16 | | | 0.09 | | | | |
| | Total | 0.45 | 1.48 | 12.05 | 0.0 | 0.72 | 11.58 | 0.0 | 0.59 | 11.93 |
| 1978 | R | 2.10 | 0.30 | 18.16* | 0.85 | 0.11 | 14.83* | 0.63 | 0.48 | 15.85* |
| | R + I | 0.74 | 0.14 | 1.99* | 0.03 | 0.04 | 3.98* | 0.05 | 0.11 | 1.99* |
| | I | | | 0.12 | | 0.06 | 0.07 | | 0.01 | 0.29 |
| | Total | 2.84 | 0.44 | 20.27 | 0.88 | 0.21 | 18.88 | 0.68 | 0.60 | 18.13 |

*Value includes one or more runoff events where collection barrel overflowed. Rainfall runoff was adjusted using the SCS runoff curve number method when barrels overflowed. Irrigation and irrigation-rainfall mixed runoff were not adjusted.

## TABLE 31. ANNUAL RAINFALL PLUS IRRIGATION AND TOTAL RUNOFF PERCENT

| Year | Rainfall, cm | Rainfall plus irrigation, cm | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | High | | | Medium | | | Low | | |
| | | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 |
| 1973 | 74.3[§] | 129.1 | 129.1 | 129.1 | 101.7 | 101.7 | 101.7 | 88.0 | 88.0 | 88.0 |
| 1974 | 117.9 | 178.7 | 178.7 | 178.7 | 148.3 | 148.3 | 148.3 | 133.1 | 133.1 | 133.1 |
| 1975 | 136.9 | 194.1 | 194.1 | 194.1 | 165.5 | 165.5 | 165.5 | 151.2 | 151.2 | 151.2 |
| 1976 | 98.0 | 154.4 | 148.2 | 149.9 | 120.9 | 127.8 | 134.5 | 111.3 | 114.3 | 113.2 |
| 1977 | 119.9 | 164.9 | 165.0 | 172.3 | 139.3 | 141.6 | 148.1 | 134.4 | 131.5 | 135.7 |
| 1978 | 110.1 | 155.2 | 159.0 | 163.5 | 134.7 | 132.8 | 134.9 | 123.0 | 118.9 | 119.7 |
| 1979 | 134.0 | 225.2 | 215.0 | 225.8 | 183.5 | 172.3 | 180.7 | 155.6 | 157.9 | 154.6 |

| Year | | Total runoff as percent of rainfall plus irrigation[#] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | High | | | Medium | | | Low | | |
| | | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 |
| 1973[§] | | 9.3 | 8.2 | 12.4 | 6.3 | 4.6 | 12.2 | 9.8 | 1.4 | 12.3 |
| 1974 | | 3.6 | 6.1 | 9.9 | 2.5 | 3.0 | 10.1[+] | 4.2 | 1.6 | 11.5 |
| 1975 | | 2.4[*] | 3.6[*,+] | 8.3[*] | 1.9[*] | 2.4[*] | 7.7[*] | 2.6[*] | 2.5[*] | 11.3[*,+] |
| 1976 | | 0.1 | 0.2 | 6.9[*] | 0 | 0 | 4.1[*] | 0.1 | 0 | 7.0[*] |
| 1977 | | 0.3 | 0.9 | 7.0[*] | 0 | 0.5 | 7.8[*] | 0 | 0.4 | 8.8[*] |
| 1978 | | 1.8 | 0.3 | 12.4[*,+] | 0.6 | 0.2 | 14.0[*,+] | 0.6 | 0.5 | 15.1[*,+] |
| | Mean | 3.0 | 3.2 | 9.5 | 1.9 | 1.8 | 9.3 | 2.9 | 1.1 | 11.0 |

[§] Rainfall total is for April 27, 1973 through Dec. 31, 1973 because runoff was not collected before this starting date. Total rainfall for 1973 was 110.5 cm.

[#] Using runoff totals from Table 30.

[*] Includes rainfall runoff event(s) when barrel overflowed and total runoff was adjusted (increased) using SCS runoff number method.

[+] Includes rainfall-irrigation mixed runoff event(s) when barrel overflowed, but no adjustments were made.

TABLE 32. RAINFALL RUNOFF FROM FERTILIZED PLOTS

| Year | Rainfall (cm) | Rainfall runoff, cm | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Grazing, 1.6 x 6.5 m | | Hay, 1.6 x 6.5 m | | Grazing, 2.3 x 4.6 m | | Hay, 2.3 x 4.6 m | |
| | | Plot 10 | Plot 12 | Plot 11 | Plot 13 | Plot 100 | Plot 120 | Plot 110 | Plot 130 |
| 1975* | 136.9 | 13.33 | 13.50 | 13.50 | 12.18 | — | — | — | — |
| 1976 | 98.0 | 3.62 | 2.43 | 2.51 | 1.90 | 4.16 | 1.21 | 2.85 | 1.58 |
| 1977 | 119.9 | 8.10 | 4.97 | 7.08 | 5.02 | 8.81 | 6.60 | 3.99 | 3.14 |
| 1978* | 110.1 | 13.03 | 9.23 | 10.76 | 9.13 | 15.34 | 8.73 | 8.80 | 5.60 |
| Total (1976-1978) | | 24.75 | 16.63 | 20.35 | 16.05 | 28.31 | 16.54 | 15.64 | 10.32 |
| | | Percent of rainfall | | | | | | | |
| 1975* | | 9.7 | 9.9 | 9.9 | 8.9 | - - | - - | - - | - - |
| 1976 | | 3.7 | 2.5 | 2.6 | 1.9 | 4.2 | 1.2 | 2.9 | 1.6 |
| 1977 | | 6.8 | 4.1 | 5.9 | 4.2 | 7.3 | 5.5 | 3.3 | 2.6 |
| 1978* | | 11.8 | 8.4 | 9.9 | 8.3 | 13.9 | 7.9 | 8.0 | 5.1 |

*Total runoff amount includes one or more events where collection barrel overflowed and runoff was estimated using the SCS runoff curve number method. Additional amounts (above actually measured) estimated for 1975 and 1978 were 7.07 and 1.74 cm, respectively.

Mean annual runoff volumes for treatments and the annual mean for all topdressed plots are given in Table 33. The high treatment consistently had the most rain runoff and total runoff annually, but variability between plots was such that the differences between treatment means were usually not significant at the 5% level using Duncan's test. The mean annual rain runoff from the fertilized plots was usually greater than the treatment means for the irrigated plots. The fertilized plots were not in the random block design and were not compared statistically to the irrigated treatments. However, the high runoff from fertilized plots compared to irrigation treatment means was due to the fertilized plots all being located in soil with a relatively shallow A horizon similar to Block 3. Therefore, the slight differences in soil profiles seemed to have more influence on runoff than the irrigation treatments which usually received from 0.5 to 2 cm of liquid weekly during the growing season.

Percent of annual runoff occurring during the irrigation season (usually April through September) was variable for all treatments from year to year (Table 33). However, the treatments had similar percent runoff for any one year. The high percent runoff for the first year was partly because runoff collection did not begin until April 1973. Thus, again, irrigation did not seem to have much influence on runoff for this soil-cropping system when irrigation was only during this crop-growing season. Most runoff occurred during a few periods of prolonged rainy weather, especially in winter months when the soil tended to stay saturated. Also, July 1975 was an extremely rainy month. Overall, however, the runoff volumes from these plots were relatively low which would be expected for soil such as this Norfolk sandy loam on a low slope (1-3%).

The effect of Block or Replication 3 being in an area of more shallow A horizon is evident when replication means are compared (Table 34). For all years, both rain runoff and total runoff from Block 3 were significantly greater than Blocks 1 and 2 except for rain runoff from Block 1 in 1973. In almost all cases, there were no significant differences between Blocks 1 and 2. This again emphasizes the influence of slight differences in the soil profile. Percent of runoff occurring during the irrigation season was variable between replications and between years, but on the average the percent was lower for Replication 3. This was probably due to quicker saturation of the A horizon in Replication 3 during the winter months. The runoff difference between Blocks 1 and 2 and Block 3 was greater in winter than during the irrigation season.

Linear and non-linear regressions of runoff volume as the dependent variable indicated that there was little correlation between runoff volumes and rainfall amounts. Runoff events analyzed by plot, by treatment, and all events together gave correlation coefficients from 0.2 to 0.5. Using only Block 2 from 1976 through 1978, during which no barrels overflowed, regression of monthly rain runoff volumes as dependent upon such quantities as (1) monthly rainfall minus estimated evapotranspiration (ET), (2) monthly rainfall plus irrigation minus ET, and (3) monthly rainfall plus irrigation gave correlation coefficients again of only about 0.2 to 0.5. Looking at individual rainfall events and runoff indicated that runoff volumes were variable between plots and were not very consistent for the same size

## TABLE 33. MEAN RUNOFF VOLUMES FOR TREATMENTS*

| | Rain runoff volume, cm | | | | Total runoff volume, cm | | |
|---|---|---|---|---|---|---|---|
| Year | H | M | L | F | H | M | L |
| 1973 | 9.75 | 6.85 | 6.61 | -- | 12.87a | 7.84b | 6.91b |
| 1974 | 8.88 | 6.71 | 6.90 | -- | 11.73 | 7.74 | 7.68 |
| 1975 | 8.67 | 6.50 | 8.00 | 13.13 | 9.26 | 6.62 | 8.27 |
| 1976 | 2.95 | 1.82 | 2.41 | 2.53 | 3.61 | 1.83 | 2.70 |
| 1977 | 4.44 | 4.04 | 4.17 | 5.96 | 4.66a | 4.10b | 4.17b |
| 1978 | 6.85 | 5.26 | 5.65 | 10.08 | 7.85 | 6.66 | 6.47 |
| Mean | 6.92 | 5.20 | 5.62 | 7.92 | 8.33a | 5.80b | 6.03ab |
| | Runoff during irrigation season only, cm | | | | | | |
| 1973 | 9.59 | 6.75 | 6.44 | -- | 12.73a | 7.74b | 6.78b |
| 1974 | 5.34 | 4.66 | 4.07 | -- | 8.19 | 5.72 | 4.91 |
| 1975 | 4.93a | 3.56b | 4.35ab | -- | 5.42 | 3.68 | 4.64 |
| 1976 | 0.03 | 0.00 | 0.00 | -- | 0.69 | 0.01 | 0.29 |
| 1977 | 1.60a | 1.33b | 1.37ab | -- | 1.82a | 1.40b | 1.40b |
| 1978 | 1.23 | 0.20 | 0.63 | -- | 2.23 | 1.60 | 1.45 |
| Mean | 3.79 | 2.75 | 2.81 | -- | 5.18 | 3.36 | 3.24 |
| | Percent runoff occurring during irrigation season | | | | | | |
| 1973 | 98 | 99 | 97 | -- | 99 | 99 | 98 |
| 1974 | 60 | 69 | 59 | -- | 70 | 74 | 64 |
| 1975 | 57 | 55 | 54 | -- | 58 | 56 | 56 |
| 1976 | 1 | 0 | 0 | -- | 19 | 0 | 11 |
| 1977 | 36 | 33 | 33 | -- | 39 | 34 | 34 |
| 1978 | 18 | 4 | 11 | -- | 28 | 24 | 22 |
| Mean | 45 | 43 | 42 | -- | 52 | 48 | 48 |

*Irrigated treatments are 3 levels (High-H, Medium-M, and Low-L) with 3 replications. Values for the fertilized plots (F) are the means of all plots given in Table 32. Values followed by different letters represent significant difference at the 5% level.

## TABLE 34. MEAN RUNOFF VOLUMES FOR REPLICATIONS*

| | Rain runoff volume, cm | | | | Total runoff volume, cm | | |
|---|---|---|---|---|---|---|---|
| Year | 1 | 2 | 3 | F | 1 | 2 | 3 |
| 1973 | 7.61ab | 4.53b | 11.07a | -- | 9.06b | 5.48b | 13.08a |
| 1974 | 4.41b | 4.27b | 13.81a | -- | 5.26b | 5.86b | 16.03a |
| 1975 | 3.79b | 4.43b | 14.95a | 13.13 | 3.94b | 4.89b | 15.31a |
| 1976 | 0.04b | 0.00b | 7.15a | 2.53 | 0.11b | 0.12b | 7.91a |
| 1977 | 0.02c | 0.78b | 11.85a | 5.96 | 0.15c | 0.93b | 11.85a |
| 1978 | 1.19b | 0.30b | 16.28a | 10.08 | 1.47b | 0.42b | 19.09a |
| Mean | 2.84b | 2.38b | 12.52a | 7.92 | 3.33b | 2.95b | 13.88a |
| | | | Runoff during irrigation season, cm | | | | |
| 1973 | 7.40ab | 4.37b | 11.01a | -- | 8.84b | 5.38b | 13.04a |
| 1974 | 3.93a | 3.86a | 6.28a | -- | 4.82a | 5.47a | 8.53a |
| 1975 | 1.95b | 2.39b | 8.51a | -- | 1.98b | 2.86b | 8.89a |
| 1976 | 0.00a | 0.00a | 0.03a | -- | 0.07a | 0.12a | 0.80a |
| 1977 | 0.02c | 0.57b | 3.71a | -- | 0.15c | 0.76b | 3.70a |
| 1978 | 0.10b | 0.10b | 1.87a | -- | 0.37b | 0.22b | 4.68a |
| Mean | 2.23b | 1.88b | 5.24a | -- | 2.71b | 2.47b | 6.61a |
| | | | Percent runoff occurring during irrigation season | | | | |
| 1973 | 97 | 96 | 99 | -- | 98 | 98 | 100 |
| 1974 | 89 | 90 | 45 | -- | 92 | 93 | 53 |
| 1975 | 51 | 54 | 57 | -- | 50 | 58 | 58 |
| 1976 | 0 | 0 | 0 | -- | 64 | 100 | 10 |
| 1977 | 100 | 73 | 31 | -- | 100 | 82 | 31 |
| 1978 | 8 | 33 | 11 | -- | 25 | 52 | 25 |
| Mean | 58 | 58 | 40 | -- | 72 | 80 | 46 |

---

[*] Mean values for each of three blocks (1, 2, and 3) of randomized block design with three treatments and three replications. Values for the fertilized plots (F) are the means of all plots given in Table 32. Values followed by same letter are not significantly different at the 5% level.

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rainfall events. Antecedent moisture and rainfall intensity were probably the major influences on rainfall runoff. These factors were not included in the regression analyses. However, the main objective of the runoff experiment was to determine the effects of irrigation treatments on runoff quantity and quality. Overall, the quantity of runoff was relatively low for all treatments and slight differences in the soil profile between blocks had more effect than irrigation treatments. If irrigation was continued through the winter months, treatment differences would likely result because of differences in irrigation liquid volume and the saturated condition of the soil in winter months which would promote more runoff from the plots receiving more irrigation.

## CONCENTRATIONS IN SURFACE RUNOFF

Surface runoff from irrigation, rainfall, and irrigation-rainfall mixed events was sampled and analyzed for nutrients, chemical oxygen demand, metals, and various other constituents. Runoff that included irrigation was analyzed for each event for TKN, $NO_3$-N, P, COD, TOC and $Cl^-$. Metals and cations such as Na and K were analyzed for a monthly composite sample of rain runoff starting in March 1975. Samples from events during the month were composited for each plot based on runoff volumes for the different events.

### Irrigation Runoff Concentrations

Irrigation runoff volumes were seldom a significant percentage of the volume of irrigation applied, but the concentrations often approached the levels of the irrigated lagoon effluent. Thus, the irrigation runoff had high pollution potential from a pollutant concentration standpoint. The actual pollution impact would depend on the volume of runoff reaching a stream or pond compared to the stream flow or pond volume, and how much infiltration or treatment of runoff could be provided by a buffer or infiltration strip between the irrigated site and the stream or pond.

Mean annual concentrations of selected runoff constituents are presented in Table 35. Both the aritimetic mean and the volume-weighted mean concentrations are presented as well as number of runoff events and annual runoff volume for each plot. Concentrations are variable but most are very high and approach the levels measured for irrigated lagoon effluent collected in cups on the plots. Overall, there were not many irrigation runoff events after the first year (1973), but because concentrations were high, the mass transport of pollutants was not negligible compared to transport by rainfall runoff. Some of the larger runoff events were due to clogging of the nozzle nearest the runoff subplot.

### Irrigation-Rainfall Mixed Runoff Concentrations

Concentrations of pollutants in irrigation-rainfall mixed runoff were often very high, but were variable because of varying rainfall runoff dilution. There were not many mixed runoff events, but they did represent a high pollution potential because of the high concentrations and the increased

## TABLE 35. IRRIGATION RUNOFF MEAN ANNUAL CONCENTRATIONS

| Plot | Year | No. runoff events | Annual runoff (cm) | TKN n* | TKN M1† mg/ℓ | TKN M2‡ mg/ℓ | P n | P M1 mg/ℓ | P M2 mg/ℓ | COD n | COD M1 mg/ℓ | COD M2 mg/ℓ | TOC n | TOC M1 mg/ℓ | TOC M2 mg/ℓ | Cℓ n | Cℓ M1 mg/ℓ | Cℓ M2 mg/ℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1973 | 8 | 2.80 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 1974 | 3 | 0.42 | 2 | 184 | 128 | 1 | 78 | 78 | 3 | 510 | 489 | - | - | - | - | - | - |
| | 1975 | 2 | 0.36 | 2 | 252 | 199 | 1 | 52 | 52 | 2 | 278 | 363 | 1 | 420 | 420 | - | - | - |
| | 1976 | 2 | 0.12 | 2 | 127 | 127 | 2 | 39 | 39 | 2 | 633 | 633 | 2 | 195 | 195 | 2 | 103 | 103 |
| 4 | 1973 | 12 | 2.63 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 1974 | 8 | 2.95 | 6 | 259 | 199 | 3 | 61 | 60 | 4 | 697 | 812 | 1 | 415 | 415 | 2 | 244 | 237 |
| | 1975 | 2 | >0.97§ | 2 | 276 | 216 | 1 | 70 | 70 | 2 | 356 | 368 | 1 | 575 | 575 | - | - | - |
| | 1976 | 2 | 0.34 | 2 | 262 | 282 | 2 | 66 | 62 | 2 | - | - | 2 | 380 | 342 | 2 | 139 | 140 |
| | 1977 | 5 | 0.16 | 4 | 268 | 277 | 5 | 51 | 52 | 5 | 483 | 498 | 5 | 179 | 177 | 5 | 146 | 150 |
| 7 | 1973 | 6 | 2.59 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 1974 | 5 | 0.89 | - | - | - | - | - | - | 4 | 636 | 802 | 1 | 340 | 340 | 1 | 248 | 248 |
| | 1975 | 1 | 0.03 | - | - | - | - | - | - | 1 | 338 | 338 | - | - | - | - | - | - |
| | 1976 | 2 | 0.34 | 2 | 188 | 264 | 2 | 61 | 76 | 2 | 552 | 477 | 2 | 200 | 245 | 2 | 115 | 135 |
| | 1978 | 1 | 0.12 | 1 | 15 | 15 | 1 | 11 | 11 | 1 | 109 | 109 | 1 | 37 | 37 | 1 | 9 | 9 |
| 3 | 1973 | 3 | 0.72 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 1974 | 1 | 0.05 | 1 | 146 | 146 | 1 | 5 | 5 | 1 | 143 | 143 | - | - | - | - | - | - |
| 5 | 1973 | 3 | 0.22 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 1974 | 1 | 0.09 | 1 | 2 | 2 | 1 | 5 | 5 | 1 | 85 | 85 | - | - | - | - | - | - |
| | 1975 | 1 | 0.01 | 1 | 301 | 301 | - | - | - | 1 | 245 | 245 | 1 | 430 | 430 | - | - | - |
| | 1977 | 4 | 0.09 | 4 | 244 | 234 | 4 | 47 | 47 | 4 | 503 | 504 | 4 | 193 | 202 | 4 | 140 | 144 |
| | 1978 | 1 | 0.06 | 1 | 287 | 287 | 1 | 61 | 61 | 1 | 529 | 529 | 1 | 105 | 105 | 1 | 136 | 136 |
| 9 | 1973 | 9 | 1.56 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 1975 | 1 | 0.19 | 1 | 176 | 176 | 1 | 58 | 58 | 1 | 442 | 442 | - | - | - | - | - | - |
| | 1978 | 1 | 0.07 | 1 | 13 | 13 | 1 | 6 | 6 | 1 | 109 | 109 | 1 | 28 | 28 | 1 | 13 | 13 |
| 2 | 1973 | 4 | 0.32 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 1974 | 2 | 0.24 | 2 | 78 | 54 | 1 | 40 | 40 | 2 | 199 | 179 | - | - | - | - | - | - |
| 6 | 1978 | 1 | 0.01 | 1 | 248 | 248 | 1 | 68 | 68 | 1 | 612 | 612 | 1 | 280 | 280 | 1 | 134 | 134 |
| 8 | 1973 | 1 | 0.10 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | 1974 | 1 | 0.08 | 1 | 8 | 8 | 1 | 5 | 5 | 1 | 151 | 151 | - | - | - | - | - | - |
| | 1975 | 1 | >0.81§ | 1 | 36 | 36 | 1 | 65 | 65 | 1 | 162 | 162 | - | - | - | - | - | - |
| | 1976 | 1 | 0.84 | 1 | 199 | 199 | 1 | 60 | 60 | 1 | 1,035 | 1,035 | 1 | 330 | 330 | 1 | 108 | 108 |
| | 1978 | 1 | 0.29 | 1 | 13 | 13 | 1 | 6 | 6 | 1 | 109 | 109 | 1 | 40 | 40 | 1 | 10 | 10 |

*n - Number of events with concentration data.

†M1 - Arithmetic mean concentration.

‡ M2 - Volume - weighted concentration.

§ - Includes event where collection barrel overflowed.

runoff potential when irrigation and rainfall occurred at or near the same time. The events with higher runoff volumes usually had concentrations similar to rain runoff. However, a few events had high concentrations and high runoff volumes. These events occurred when the soil was nearly saturated before irrigation or when nozzles clogged.

Mean annual concentrations of selected constituents are presented in Table 36. Most plots had zero to two events per year. Runoff events less than 0.01 cm were not included. Overall, these mixed runoff events were usually small and infrequent. However, a few of these events represented a large percentage of the mass transport in surface runoff.

## Rainfall Runoff Concentrations

Mean concentrations of selected runoff constituents, number of runoff events, and information concerning the event with highest concentration are presented in Tables E-1 through E-6 for each plot for each year. Arithmetic mean concentrations were normally greater than volume-weighted concentrations, which indicated that smaller runoff events tended to have higher concentrations. Also, the standard deviation was normally about equal to the mean value, which indicated large variability between events. The number of events greater than 0.01 cm in volume was always less than 20 each year and was often less than 10. The topdressed plots normally had less variability and lower mean concentrations than the irrigated plots but each year some irrigated plots, usually the low-rate irrigation plots, had concentrations similar to the topdressed plots.

The highest concentration event each year for the irrigated plots usually occurred during the irrigation season (about April through September). Concentration for this event was typically two to four times greater than the annual mean concentration. Almost all of the highest concentration events occurred with less than 0.1 cm of runoff, except for the event on 9/3/74. It is suspected that this event was not recorded correctly and should have been in the irrigation-rainfall mixed runoff category.

When the highest concentration for the topdressed plots was two or more times the mean concentration, the event normally occurred within 10 days after a fertilizer application. For example, the TKN, $NO_3$-N, and $NH_3$-N concentrations were high on 7/11/78 (Tables E-1, E-2 and E-7) because ammonium nitrate fertilizer was applied to all topdressed plots on 7/6/78.

Overall, the annual mean concentrations and highest concentrations by plot show variability, for both the irrigated plots and the topdressed plots. The highest concentrations normally occurred during the irrigation season, or soon after fertilizer application in the case of the topdressed plots. Because number of runoff events and annual volume of runoff was relatively low, a single high-concentration, high-volume runoff event usually had a large influence on the annual mean concentration for a plot and for the treatment means.

## TABLE 36. IRRIGATION-RAINFALL MIXED RUNOFF MEAN ANNUAL CONCENTRATION

| Plot | Year | No. runoff events | Annual runoff (cm) | TKN M1[+] mg/ℓ | TKN M2[‡] mg/ℓ | P M1 mg/ℓ | P M2 mg/ℓ | COD M1 mg/ℓ | COD M2 mg/ℓ | TOC M1 mg/ℓ | TOC M2 mg/ℓ | Cℓ M1 mg/ℓ | Cℓ M2 mg/ℓ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1973 | 1 | 0.38 | 25 | "[§] | - | - | 298 | " | 195 | " | 54 | " |
| | 1974 | 1 | 0.82 | 10 | " | 10 | " | 83 | " | - | - | - | - |
| | 1975 | 1 | 0.09 | 310 | " | 68 | " | 919 | " | - | - | 160 | " |
| | 1976 | 2 | 0.08 | 178 | 175 | 54 | 53 | 849 | 854 | 338 | 319 | 110 | " |
| | 1977 | 1 | 0.39 | 366 | " | 60 | " | 460 | " | 120 | " | 110 | " |
| | 1978 | 3 | 0.74 | 92 | 40 | 29 | 14 | 201 | 87 | 60 | 30 | 49 | 20 |
| 4 | 1973 | 1 | 0.02 | 15 | " | - | - | 96 | " | 65 | " | 17 | " |
| | 1974 | 1 | 1.40 | - | - | 16 | " | 131 | " | - | - | - | - |
| | 1975 | 1 | 0.30 | 237 | " | - | - | 856 | " | - | - | 148 | " |
| | 1977 | 2 | 0.10 | 96 | 145 | 27 | 36 | 234 | 294 | 115 | 155 | 64 | 84 |
| | 1978 | 1 | 0.14 | 3 | " | 3 | " | 33 | " | 16 | " | 5 | " |
| 7 | 1973 | 1 | 0.96 | 11 | " | - | - | 27 | " | 20 | " | 2 | " |
| | 1974 | 1 | 2.09 | 25 | " | 12 | " | 148 | " | - | - | - | - |
| | 1976 | 2 | 1.10 | 183 | 169 | 108 | 95 | 744 | 735 | 228 | 220 | 110 | 106 |
| | 1978 | 1 | >1.99* | 15 | " | 10 | " | 117 | " | 26 | | 9 | " |
| 3 | 1973 | 1 | 0.05 | 12 | " | - | - | 169 | " | 90 | " | 93 | " |
| | 1974 | 1 | 0.46 | 3 | " | 5 | " | 47 | " | - | - | - | - |
| | 1976 | 1 | 0.01 | 60 | " | 24 | " | 443 | " | 140 | " | 59 | " |
| | 1978 | 1 | 0.03 | 6 | " | 3 | " | 46 | " | 16 | " | 4 | " |
| 5 | 1974 | 1 | 0.31 | 4 | " | 5 | " | 49 | " | - | - | - | - |
| | 1975 | 1 | 0.10 | 276 | " | 50 | " | 888 | " | - | - | 138 | " |
| | 1977 | 2 | 0.10 | 48 | 57 | 19 | 22 | 160 | 169 | 72 | 76 | 35 | 39 |
| | 1978 | 2 | 0.04 | 128 | 134 | 34 | 35 | 280 | 297 | 70 | 76 | 90 | 96 |
| 9 | 1973 | 1 | 0.40 | 4 | " | - | - | 21 | " | 18 | " | - | - |
| | 1974 | 1 | 2.16 | 75 | " | 3 | " | 367 | " | - | - | - | - |
| | 1975 | 1 | 0.04 | 130 | " | - | - | 430 | " | - | - | 84 | " |
| | 1976 | 1 | 0.01 | 28 | " | 10 | " | 292 | " | 80 | " | 43 | " |
| | 1978 | 2 | >3.98* | 112 | 112 | 37 | 37 | 196 | 196 | 50 | " | 50 | 50 |
| 2 | 1973 | 1 | 0.06 | 8 | " | - | - | 117 | " | 73 | " | 42 | " |
| | 1974 | 1 | 0.58 | 4 | " | 29 | " | 50 | " | - | - | - | - |
| | 1978 | 1 | 0.05 | 6 | " | 3 | " | 37 | " | 13 | " | 4 | " |
| 6 | 1976 | 1 | 0.03 | 5 | " | 3 | " | 38 | " | 220 | " | 136 | " |
| | 1978 | 1 | 0.11 | 234 | " | 128 | " | 563 | " | 14 | " | 4 | " |
| 8 | 1973 | 1 | 0.43 | 11 | " | - | - | 35 | " | 24 | " | 2 | " |
| | 1974 | 1 | 1.46 | 4 | " | 4 | " | 53 | " | - | - | - | - |
| | 1977 | 1 | 0.01* | 48 | " | 37 | " | 465 | " | 105 | " | 76 | " |
| | 1978 | 1 | >1.99 | 17 | " | 8 | " | 115 | " | 30 | " | 12 | " |

[+] M1 - Arithmetic mean concentration

[‡] M2 - Volume-weighted concentration

[§] - "indicates M2 = M1 because only one event

* - Includes event(s) where barrel overflowed.

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Annual mean volume-weighted concentrations for irrigated treatments and blocks (replications) are given in Table 37 for TKN, $NO_3$-N, P and $Cl^-$. The treatment and replication mean concentrations seldom were different at the 5% significance level using Duncan's test. The high-rate treatment had significantly higher mean concentrations than the medium-rate and low-rate treatments in 1975 for TKN, $NO_3$-N and P. The only other year with significant treatment differences was 1976, but the low-rate treatment had the highest concentration except for P. P was the only nutrient that was consistently highest on the high-rate treatment, but the difference was only significant at the 5% level in 1975 and 1976. The averages of the six years of concentration data were highest on the high-rate treatment for all nutrients, but only P tested to be significantly higher at the 5% level. The ranges of treatment annual mean concentrations excluding 1974 data were about 3 to 12 mg/l for TKN, 1 to 7 mg/l for $NO_3$-N, 4 to 14 mg/l for total N, 1 to 9 mg/l for P, and 2 to 10 mg/l for $Cl^-$. In 1974, extremely high concentration values were recorded for runoff for 9/3/74 which is suspected to have included irrigation runoff. Also extremely high $NO_3$-N values were recorded for 11/20/74 and this data is suspected to have sampling error.

Mean concentrations for Replication 3 were significantly lower only in 1976 (Table 37), even though the volume of runoff from Replication 3 was significantly greater every year except 1973. Thus, an increase in runoff volume did not necessarily result in a corresponding decrease in concentration.

Annual mean volume-weighted concentrations of selected nutrients in runoff from the topdressed plots are given for years 1975 through 1978 in Table E-9. For any particular year the concentrations were similar for all plots. The average concentrations of the eight topdressed plots (Table 38) were fairly constant from year to year compared to the data from the irrigated treatments. Comparison of mean concentrations for irrigated treatments and topdressed plots for the years 1975 through 1978 (Table 39) show that the topdressed plots had the lowest mean concentration each year. However, the topdressed plots were not part of the randomized block design and differences were not tested statistically.

## MASS TRANSPORT IN SURFACE RUNOFF

The amount of mass of selected nutrients annually transported in runoff was estimated by multiplying total annual runoff by the volume-weighted annual mean concentration of events that had concentration data for that year. Mass transport for each of the three types of runoff categories are presented for selected constituents in Tables F-1 through F-7 for each of the irrigated plots. For a few large runoff events the runoff collection barrel overflowed. When this occurred, the runoff volumes were adjusted for rainfall runoff events using the SCS curve number method as previously mentioned, but volumes were not adjusted when overflow occurred with irrigation or irrigation-rainfall mixed runoff. These limitations should be realized when viewing this data.

## TABLE 37. TREATMENT VOLUME-WEIGHTED CONCENTRATION IN RAINFALL RUNOFF[+]

Treatment mean volume-weighted concentration, mg/l

| Year | TKN | | | NO3-N | | | TKN + NO3-N | | |
|---|---|---|---|---|---|---|---|---|---|
| | H | M | L | H | M | L | H | M | L |
| 1973 | 3.2a | 3.8a | 5.1a | 2.0a | 1.9a | 3.0a | 5.2a | 5.7a | 8.1a |
| 1974[δ] | 16.0a | 8.7a | 6.0a | 36.4a | 8.5a | 3.3a | 52.4a | 17.2a | 9.3a |
| 1975 | 7.5a | 3.3b | 3.6b | 6.6a | 2.0b | 1.7b | 14.1a | 5.3b | 5.3b |
| 1976 | 3.0b | 2.9c | 7.0a | 2.5c | 3.5b | 5.5a | 5.5c | 6.4b | 12.5a |
| 1977 | 6.0a | 12.0a | 2.8a | 2.7a | 2.2a | 1.2a | 8.8a | 14.2a | 4.0a |
| 1978 | 5.8a | 5.4a | 3.5a | 4.1a | 6.0a | 1.9a | 9.9a | 11.4a | 5.4a |
| 1973-78 | 7.4a | 6.0a | 4.6a | 9.8a | 4.2a | 2.7a | 17.3a | 10.2a | 7.3a |

| Year | P | | | Cl⁻ | | |
|---|---|---|---|---|---|---|
| | H | M | L | H | M | L |
| 1973 | 3.6a | 1.8a | 1.2b | 3.6a | 3.1a | 3.5a |
| 1974 | 3.3a | 2.4a | 1.8a | 19.3a | 19.4a | 17.2a |
| 1975 | 9.2a | 2.2b | 2.4b | 10.4a | 6.0a | 5.3a |
| 1976 | 5.1a | 2.5c | 2.6b | 2.0c | 2.7b | 6.8a |
| 1977 | 9.0a | 8.3a | 1.8a | 5.8a | 8.7a | 2.8a |
| 1978 | 5.0a | 4.2a | 2.1a | 3.3a | 4.9a | 1.7a |
| 1973-78 | 6.0a | 3.4b | 2.0b | 8.1a | 8.0a | 6.4a |

Replication mean volume-weighted concentration, mg/l

| Year | TKN | | | NO3-N | | | TKN + NO3-N | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1[*] | 2[*] | 3[*] | 1 | 2 | 3 | 1 | 2 | 3 |
| 1973 | 3.4a | 5.0a | 3.6a | 1.5a | 4.2a | 1.2a | 5.0a | 9.3a | 4.8a |
| 1974 | 12.0a | 7.4a | 11.3a | 33.1a | 12.1a | 3.0a | 45.1a | 19.5a | 14.3a |
| 1975 | 4.0a | 4.5a | 5.9a | 2.0a | 4.2a | 4.1a | 6.0a | 8.7a | 10.0a |
| 1976 | 11.4a | - | 2.9b | 9.1a | - | 2.6b | 20.4a | - | 5.5b |
| 1977 | 5.2a | 10.8a | 3.4a | 2.3a | 2.5a | 1.7a | 7.5a | 13.2a | 5.1a |
| 1978 | 5.1a | 6.2a | 3.3a | 4.0a | 5.2a | 2.8a | 9.1a | 11.4a | 6.2a |
| 1973-78 | 6.4a | 6.8a | 5.1a | 9.5a | 5.6a | 2.6a | 16.0a | 12.4a | 7.6a |

| Year | P | | | Cl⁻ | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 1 | 2 | 3 |
| 1973 | 2.4a | 2.2a | 2.1a | 3.5a | 3.1a | 3.6a |
| 1974 | 1.6a | 3.2a | 2.7a | 15.5a | 21.6a | 18.9a |
| 1975 | 4.8a | 5.4a | 3.5a | 8.8a | 6.8a | 6.0a |
| 1976 | 3.6a | - | 3.1b | 10.9a | - | 2.5b |
| 1977 | 5.7a | 9.1a | 4.9a | 6.7a | 8.5a | 2.8a |
| 1978 | 5.0a | 3.6a | 2.6a | 2.8a | 5.0a | 2.2a |
| 1973-78 | 3.6a | 4.7a | 3.1a | 7.8a | 9.0a | 6.0a |

[+] Treatment (High - H, Medium - M, and Low - L) means and replication (three replications) means of volume-weighted concentrations. Values followed by same letter are not significantly different at the 5% level.

[*] Replication number.

[δ] Nitrate values were extremely high for one event (11/20/74) which resulted in high means for 1974. Sampling or chemical analysis errors were suspected, but could not be documented.

TABLE 38. VOLUME-WEIGHTED CONCENTRATION IN RAIN RUNOFF FROM FERTILIZED PLOTS - ANNUAL MEAN OF ALL PLOTS*

| | Concentration, mg/l | | | |
|---|---|---|---|---|
| Constituent | 1975 | 1976 | 1977 | 1978 |
| TKN | 3.1 | 1.6 | 2.4 | 2.9 |
| $NO_3$-N | 0.9 | 0.5 | 0.4 | 1.2 |
| TKN + $NO_3$-N | 4.0 | 2.1 | 2.8 | 4.1 |
| P | 0.3 | 0.2 | 0.3 | 0.5 |
| $Cl^-$ | 2.0 | 2.0 | 1.9 | 1.8 |
| TOC | - | 13.4 | 9.9 | 10.5 |

*Mean of all plots given in Table E-9.

Normally, very little mass was transported by any of the three types of runoff compared to amounts applied by irrigation of lagoon effluent. However there were a few events within each runoff category where relatively large amounts of mass was transported (Tables F-1 through F-7). Again, the 1974 rainfall runoff data is thought to include an event (9/3/74) when irrigation runoff was mixed with rainfall runoff and one event (11/20/74) when nitrate was extremely high; thus, the mass for 1974 rainfall runoff is relatively high. Generally, the amount of runoff volume and mass transport for 1976-1978 was lower than for 1973-1975, except for Replication 3 (plots 7, 8 and 9) which had much more runoff than the other two replications. The hydrologic conditions of the plots apparently affected nutrient mass transport more than the loading rate of nutrients.

Treatment means of the estimated annual mass transport is presented for selected constituents in Table 40 for rainfall runoff and for total runoff (including irrigation and irrigation-rainfall mixed runoff). Treatments were seldom significantly different at the 5% level using Duncan's test. Differences were usually the same for total runoff as for rainfall runoff. The high-rate treatment had significantly higher mass transport in rainfall runoff in 1975 for $NO_3$-N, P and $Cl^-$. Also, the averages of the six years were significantly higher on the high-rate treatment for total N and P. However, the data generally shows that the mass transport was variable from plot to plot, even within treatments, and that the mass transport by only rainfall runoff was very low compared to nutrient loading rates, e.g. generally less than 1% for nitrogen. Highest transport was in 1974 when irrigation runoff may be included in one event. When irrigation runoff and irrigation-rainfall mixed runoff is included, mass transport is substantially increased over just rainfall runoff transport in a few cases. If irrigation had been avoided during rainy periods, the mass transport would probably have been much less in these cases.

TABLE 39. TREATMENT MEANS OF VOLUME-WEIGHTED CONCENTRATIONS IN RAIN RUNOFF*

| Year | Concentration in rain runoff, mg/l | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | TKN | | | | $NO_3$-N | | | |
| | H | M | L | F$^\delta$ | H | M | L | F$^\delta$ |
| 1975 | 7.5a | 3.3b | 3.6b | 3.1 | 6.6a | 2.0b | 1.7b | 0.9 |
| 1976 | 3.0b | 2.9c | 7.0a | 1.6 | 2.5c | 3.5b | 5.5a | 0.5 |
| 1977 | 6.0a | 12.0a | 2.8a | 2.4 | 2.7a | 2.2a | 1.2a | 0.4 |
| 1978 | 5.8a | 5.4a | 3.5a | 2.9 | 4.1a | 6.0a | 1.9a | 1.2 |
| | P | | | | $Cl^-$ | | | |
| | H | M | L | F | H | M | L | F |
| 1975 | 9.2a | 2.2b | 2.4b | 0.3 | 10.4a | 6.0a | 5.3a | 2.0 |
| 1976 | 5.1a | 2.6b | 2.5c | 0.2 | 2.0c | 2.7b | 6.8a | 2.0 |
| 1977 | 9.0a | 8.3a | 1.8a | 0.3 | 5.8a | 8.7a | 2.8a | 1.9 |
| 1978 | 5.0a | 4.2a | 2.1a | 0.5 | 3.3a | 4.9a | 1.7a | 1.8 |

*Irrigated treatments (High - H, Medium - M and Low - L) have three replications. Values followed by different letters represent significant difference at the 5% level.

$^\delta$F = Mean for fertilized plots from Table 38. These plots were not in the random block design and were not included in the statistical tests for significant difference.

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TABLE 40. TREATMENT MEAN MASS IN RUNOFF.

Mass in rainfall runoff, kg/ha[+]

| Year | TKN |  |  | $NO_3$-N |  |  | TKN + $NO_3$-N |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | H | M | L | H | M | L | H | M | L |
| 1973 | 3.03a | 2.57a | 2.77a | 1.90a | 1.10a | 1.00a | 4.93a | 3.77a | 3.67a |
| 1974 | 13.10a | 8.13a | 4.13a | 20.93a | 3.73a | 2.30a | 34.03a | 11.87a | 6.44 a |
| 1975 | 7.20a | 2.63a | 2.77a | 5.67a | 1.80b | 1.53b | 12.87a | 4.43 a | 4.30 a |
| 1976 | 0.90a | 0.53a | 0.67a | 0.73a | 0.60a | 0.50a | 1.63a | 1.13a | 1.17a |
| 1977 | 1.97a | 1.63a | 1.27a | 0.83a | 0.77a | 0.60a | 2.80a | 2.40a | 1.87a |
| 1978 | 3.40a | 1.47a | 1.57a | 2.60a | 1.37a | 1.33a | 6.00a | 2.83a | 2.90a |
| 1973-78 | 4.93a | 2.83ab | 2.19b | 5.44a | 1.56a | 1.21a | 10.38a | 4.40b | 3.41b |

| Year | P |  |  | $Cl^-$ |  |  |
|---|---|---|---|---|---|---|
|  | H | M | L | H | M | L |
| 1973 | 3.50a | 1.20b | 0.87b | 3.40a | 2.33a | 2.34a |
| 1974 | 3.60a | 1.27a | 1.03a | 17.47a | 14.20a | 10.23a |
| 1975 | 7.40a | 1.23b | 1.50b | 8.27a | 3.60b | 3.97b |
| 1976 | 1.50a | 0.47a | 0.37a | 0.60a | 0.50a | 0.67a |
| 1977 | 3.30a | 2.47a | 0.83a | 1.30a | 1.43a | 1.23a |
| 1978 | 3.40a | 0.98a | 0.90a | 2.07a | 1.10a | 0.97a |
| 1973-78 | 3.78a | 1.27b | 0.92b | 5.52a | 3.86a | 3.23a |

Mass in total runoff, kg/ha[+]

| Year | TKN |  |  | $NO_3$-N |  |  | TKN + $NO_3$-N |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | H | M | L | H | M | L | H | M | L |
| 1973 | 3.70a | 2.67a | 2.93a | 2.03a | 1.13a | 1.03a | 5.73a | 3.80a | 3.97a |
| 1974 | 36.50a | 13.90a | 4.93a | 20.93a | 3.73a | 2.30a | 57.43a | 17.63ab | 7.23b |
| 1975 | 19.77a | 5.00ab | 3.73b | 5.70a | 1.90b | 1.53b | 25.47a | 6.90b | 5.27b |
| 1976 | 14.33a | 0.57a | 6.53a | 0.83a | 0.60a | 0.50a | 15.17a | 1.17a | 7.03a |
| 1977 | 8.73a | 2.57a | 1.27a | 0.87a | 0.77a | 0.60a | 9.60a | 3.33a | 1.87a |
| 1978 | 5.47a | 17.13a | 2.97a | 3.03a | 2.90a | 1.60a | 8.50a | 20.03a | 4.57a |
| 1973-78 | 14.75a | 6.97ab | 3.73b | 5.57a | 1.84a | 1.26a | 20.32a | 8.81b | 4.99b |

| Year | P |  |  | $Cl^-$ |  |  |
|---|---|---|---|---|---|---|
|  | H | M | L | H | M | L |
| 1973 | 3.50a | 1.20b | 0.87b | 4.13a | 2.50a | 2.47a |
| 1974 | 12.47a | 1.63a | 2.13a | 48.13a | 14.20a | 10.23a |
| 1975 | 10.40a | 1.77b | 3.27b | 10.20a | 4.17b | 3.97b |
| 1976 | 6.87a | 0.47a | 2.17a | 8.33a | 0.53a | 3.83a |
| 1977 | 4.47a | 2.67ab | 0.83b | 3.80a | 2.00a | 1.27a |
| 1978 | 4.40a | 6.03a | 1.53a | 7.67a | 8.17a | 1.90a |
| 1973-78 | 7.03a | 2.29b | 1.80b | 13.71a | 5.26ab | 3.94b |

[+] Does not include events when rainfall occurred during the irrigation event.
Values followed by same letter are not significantly different at the 5% level.

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Replication (Block) means of the estimated annual mass transport are presented for selected constituents in Table 41 for rainfall runoff and for total runoff. As with runoff volumes, when significant differences occurred, Replication 3 was generally significantly higher. This again illustrates how a small difference in hydrologic properties of the soil system can have more effect on runoff and nutrient mass transport than large differences in nutrient and effluent loading rates.

Estimated mass transport of selected constituents in runoff from the fertilized plots was usually consistent between plots for any particular year for the period 1975 - 1978 (Table F-8). The annual mean mass transport from fertilized plots varied from year to year for 1975 - 1978, but the amounts of transport were relatively small, e.g. less than 5 kg TKN/ha/yr (Table 42). Comparison of the annual mean of mass in rain runoff from the irrigated treatments to that from the fertilized plots indicates relatively small differences for most years 1975 - 1978 (Table 43). However, the high-rate irrigated treatment consistently had more mass transport than the fertilized plots, but the statistical significance could not be evaluated because the fertilized plots were not in the randomized block design. Except for 1975 when there was a large amount of rain in July, the estimated amount of mass transport in rain runoff was small compared to amounts of nutrients applied.

Multiple linear regression analysis indicated that a good deal of the variation in mass yield in runoff could be explained by the nutrient loading and the runoff volume (Table 44). Analyses for rain runoff and total runoff (including irrigation and irrigation-rainfall mixed runoff) yielded similar results. Regressions for P had the best regression $R^2$ values, but even these were 0.7 and smaller. Because Replications (Block) 3 normally had much higher runoff volume than the other two blocks, regressions on Blocks 1 and 2 were performed, but the results were similar to when all blocks were included.

## SUBSURFACE RUNOFF VOLUMES

Subsurface runoff or lateral flow developed when water movement through the A horizon proceeded at a rate greater than the infiltration rate into the B horizon. Subsurface flow from drain tubes at the interface of the A and B horizons was measured for Replication 2 (plots 4, 5 and 6) for a 20-month period. During this period, July 1, 1977 to March 1, 1979, subsurface flow resulted in 29 runoff events (Table 45). An event was defined as a period of flow preceded and followed by a period of no flow. The distinction between events was clear except for periods in January and May in 1978, and February 1979, when flow was continuous for 18, 14, and 10 days, respectively. During these periods of continuous flow, several distinct rainfall events occurred. The magnitude of these rainfall events was such that each rainfall event increased the flow rate of the previous event by more than four times and thus was considered a distinct runoff event. The runoff volume associated with each of these rainfall events was considered to be the volume collected between rainfall events; however, as flow was continuous, the volume recorded with the latter events likely included runoff which was a consequence of the previous rainfall event.

## TABLE 41. REPLICATION MEAN MASS IN RUNOFF

Mass in rainfall runoff, kg/ha[+]

| Year | TKN |  |  | $NO_3$-N |  |  | N |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | 1* | 2* | 3* | 1 | 2 | 3 | 1 | 2 | 3 |
| 1973 | 2.63ab | 1.80b | 3.93a | 1.13a | 1.53a | 1.33a | 3.77a | 3.33a | 5.27a |
| 1974 | 5.73a | 4.17a | 15.47a | 17.10a | 5.87a | 4.27a | 22.83a | 10.03a | 19.73a |
| 1975 | 1.60a | 2.10a | 8.90a | 0.80b | 2.20b | 6.00a | 2.40b | 4.30b | 14.90a |
| 1976 | 0.03b | 0.00b | 2.07a | 0.03b | 0.00b | 1.80a | 0.07b | 0.00b | 3.87a |
| 1977 | 0.01b | 0.80b | 4.07a | 0.00b | 0.20b | 2.00a | 0.01c | 1.00b | 6.07a |
| 1978 | 0.73b | 0.13b | 5.57a | 0.57b | 0.07b | 4.67a | 1.30b | 0.20b | 10.23a |
| 1973-78 | 1.79b | 1.50b | 6.66a | 3.27a | 1.64a | 3.34a | 5.07ab | 3.14b | 10.04a |

| Year | P |  |  | $Cl^-$ |  |  |
|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 1 | 2 | 3 |
| 1973 | 1.90b | 1.27c | 2.40a | 2.87a | 1.31a | 3.90a |
| 1974 | 0.70a | 1.33a | 3.87a | 7.10b | 8.80b | 26.00a |
| 1975 | 1.93a | 2.77a | 5.43a | 3.33b | 3.37b | 9.13a |
| 1976 | 0.01a | 0.00a | 2.33a | 0.03b | 0.00b | 1.73a |
| 1977 | 0.01b | 0.83b | 5.77a | 0.01b | 0.67b | 3.30a |
| 1978 | 0.72ab | 0.10b | 4.47a | 0.43b | 0.10b | 3.60a |
| 1973-78 | 0.88b | 1.05b | 4.04a | 2.30b | 2.37b | 7.94a |

Mass in total runoff, kg/ha

| Year | TKN |  |  | $NO_3$-N |  |  | N |  |  |
|---|---|---|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 1 | 2 | 3 | 1 | 2 | 3 |
| 1973 | 3.00ab | 1.80b | 4.50a | 1.23a | 1.53a | 1.43a | 4.23ab | 3.33b | 5.93a |
| 1974 | 8.67a | 23.80a | 2[illegible].87a | 16.83a | 5.87a | 4.27a | 25.50a | 29.67a | 27.13a |
| 1975 | 4.87a | 12.47a | 11.17a | 0.80b | 2.23b | 6.10a | 5.67a | 14.70a | 17.27a |
| 1976 | 1.07a | 3.50a | 16.87a | 0.03b | 0.00b | 1.90a | 1.10b | 3.50ab | 18.77a |
| 1977 | 4.77a | 3.73a | 4.07a | 0.03b | 0.20b | 2.00a | 4.80a | 3.93a | 6.07a |
| 1978 | 1.70a | 1.00a | 22.87a | 0.67b | 0.07b | 6.80a | 2.37a | 1.07a | 29.67a |
| 1973-78 | 4.01b | 7.72ab | 13.72a | 3.27a | 1.65a | 3.75a | 7.32a | 9.37a | 17.49a |

| Year | P |  |  | $Cl^-$ |  |  |
|---|---|---|---|---|---|---|
|  | 1 | 2 | 3 | 1 | 2 | 3 |
| 1973 | 1.90b | 1.27c | 2.40a | 3.80a | 1.30a | 4.00a |
| 1974 | 3.03a | 8.03a | 5.17a | 7.10a | 32.10a | 33.37a |
| 1975 | 2.73a | 5.13a | 7.57a | 3.80b | 5.30ab | 9.23a |
| 1976 | 0.30a | 0.83a | 8.37a | 0.77b | 1.73ab | 10.20a |
| 1977 | 0.77b | 1.43b | 5.77a | 1.43a | 2.30a | 3.33a |
| 1978 | 1.07b | 0.30b | 10.60a | 5.37a | 0.57a | 11.80a |
| 1973-78 | 1.63b | 2.84b | 6.64a | 3.71a | 7.22a | 11.99a |

[+] Does not include events when rainfall occurred during the irrigation event.
Values followed by same letter are not significantly different at the 5% level.

[*] Replication number.

## TABLE 42. MASS IN RUNOFF FROM FERTILIZED PLOTS - ANNUAL MEAN OF ALL PLOTS*

| Constituent | Mass, kg/ha 1975 | 1976 | 1977 | 1978 |
|---|---|---|---|---|
| TKN | 4.10 | 0.38 | 1.38 | 2.68 |
| $NO_3$-N | 1.38 | 0.11 | 0.21 | 1.14 |
| Total N | 5.48 | 0.49 | 1.59 | 3.82 |
| P | 0.40 | 0.02 | 0.19 | 0.51 |
| $Cl^-$ | 2.95 | 0.51 | 1.10 | 1.72 |
| TOC | - | 3.48 | 5.75 | 10.45 |

[*] Mean of all plots given in Table F-8.

## TABLE 43. TREATMENT MEAN MASS IN RAIN RUNOFF

| Year | Mass in rain runoff, kg/ha* | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | TKN | | | | $NO_3$-N | | | |
| | H | M | L | F§ | H | M | L | F§ |
| 1975 | 7.2 | 2.6 | 2.8 | 4.1 | 5.7a | 1.8b | 1.5b | 1.4 |
| 1976 | 0.9 | 0.5 | 0.7 | 0.4 | 0.7 | 0.6 | 0.5 | 0.1 |
| 1977 | 2.0 | 1.6 | 1.3 | 1.4 | 0.8 | 0.8 | 0.6 | 0.2 |
| 1978 | 3.4 | 1.5 | 1.6 | 2.7 | 2.6 | 1.4 | 1.3 | 1.1 |
| | P | | | | $Cl^-$ | | | |
| 1975 | 7.4a | 1.2b | 1.5b | 0.4 | 8.3a | 3.6b | 4.0b | 3.0 |
| 1976 | 1.5 | 0.5 | 0.4 | 0.0 | 0.6 | 0.5 | 0.7 | 0.5 |
| 1977 | 3.3 | 2.5 | 0.8 | 0.2 | 1.3 | 1.4 | 1.2 | 1.1 |
| 1978 | 3.4 | 1.0 | 0.9 | 0.5 | 2.1 | 1.1 | 1.0 | 1.7 |

[*] Irrigated treatments (High-H, Medium-M and Low-L) have three replications. Values followed by different letters represent significant difference at the 5% level.

[§] F = Mean for eight fertilized plots, except for 1975 when only four plots were present. These plots were not in the random block design and were not included in the statistical tests for significant difference.

TABLE 44. RELATIONSHIP BETWEEN MASS YIELD RUNOFF, NUTRIENT APPLICATION LEVELS, AND RUNOFF VOLUME*

| Constituent | Rain runoff | | | | Total runoff | | | |
|---|---|---|---|---|---|---|---|---|
| | a | b | c | $R^2$ | a | b | c | $R^2$ |
| TKN | 0.0030* | 0.50** | -1.95 | 0.55 | 0.0079 | 0.84* | -3.24 | 0.29 |
| $NO_3$-N | 0.0056* | 0.16 | -2.62 | 0.18 | 0.0053* | 0.20 | -2.46 | 0.19 |
| N | 0.0086** | 0.66** | -4.58 | 0.38 | 0.0132* | 1.04** | -5.70 | 0.35 |
| P | 0.0125** | 0.30** | -2.00** | 0.71 | 0.0210** | 0.42** | -2.84* | 0.53 |
| $Cl^-$ | 0.0065 | 0.59** | -2.04 | 0.34 | 0.0237** | 0.74 | -7.53 | 0.38 |
| Reps 1 and 2 only[δ] | | | | | | | | |
| TKN | 0.0019* | 0.48** | -1.08 | 0.53 | 0.0140* | 0.94 | -7.78 | 0.43 |
| $NO_3$-N | 0.0062 | 0.50 | -3.60 | 0.19 | 0.0061 | 0.37 | -3.36 | 0.19 |
| N | 0.0081 | 0.98 | -4.67 | 0.27 | 0.0201** | 1.31 | -11.14* | 0.49 |
| P | 0.0060** | 0.28** | -0.82* | 0.60 | 0.0174* | 0.56** | -2.54 | 0.50 |
| $Cl^-$ | 0.0026 | 0.73** | -0.61 | 0.44 | 0.0228 | 1.16 | -7.96 | 0.38 |

*Regression equation $Y = a X_1 + b X_2 + C$ where

$Y$ = mass yield of runoff constituent, kg/ha/yr
$X_1$ = nutrient loading in kg/ha/yr
$X_2$ = runoff volume, cm/yr

Level of significance * 99%
** 99.9%

[δ] Mean of Rep 1 (Plots 1, 2, and 3) and Rep 2 (Plots 4, 5, and 6).

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## TABLE 45. SUBSURFACE RUNOFF BY EVENT

| Event number | Date* | Duration, days | Rain, cm | Subsurface runoff, cm<br>High (Plot 4) | Med (Plot 5) | Low (Plot 6) |
|---|---|---|---|---|---|---|
| 1 | 8-2-77 | 1 | 4.90 | 0 | trace | trace |
| 2 | 9-8-77 | 5 | 16.68 | 2.59 | 1.26 | .87 |
| 3 | 10-14-77 | 1 | 3.25 | trace | trace | 0 |
| 4 | 10-26-77 | 3 | 4.95 | .03 | .03 | .04 |
| 5 | 11-7-77 | 5 | 5.94 | 3.73 | .81 | 3.41 |
| 6 | 12-21-77 | 3 | 1.78 | .01 | .02 | .02 |
| 7 | 1-9-78 | 3 | 1.27 | .07 | .03 | .14 |
| 8 | 1-14-78 | 3 | 4.57 | 4.25 | .59 | 2.68 |
| 9+ | 1-18-78 | 2 | 1.88 | 2.25 | .26 | 1.51 |
| 10+ | 1-20-78 | 6 | 4.78 | 7.10 | 1.55 | 5.16 |
| 11+ | 1-26-78 | 7 | 2.54 | 3.65 | .67 | 2.41 |
| 12 | 2-13-78 | 1 | .89 | .02 | 0 | trace |
| 13 | 3-5-78 | 2 | 3.33 | .58 | .09 | .71 |
| 14+ | 3-10-78 | 8 | 4.88 | 4.47 | .82 | 3.97 |
| 15 | 4-26-78 | 4 | 8.30 | 6.63 | 1.26 | 5.83 |
| 16 | 5-4-78 | 2 | 1.70 | .77 | .04 | .41 |
| 17+ | 5-8-78 | 5 | 3.48 | 5.32 | .80 | 3.55 |
| 18+ | 5-15-78 | 5 | 2.62 | 2.42 | .15 | 1.10 |
| 19 | 6-7-78 | 1 | 3.33 | 0 | 0 | trace |
| 20 | 6-9-78 | 5 | 7.14 | 3.41 | .73 | 2.55 |
| 21 | 7-11-78 | 1 | 4.34 | 0 | 0 | .01 |
| 22 | 7-16-78 | 3 | 7.16 | .76 | .01 | .01 |
| 23 | 1-14-79 | 2 | 1.22 | .01 | .07 | .58 |
| 24 | 1-22-79 | 3 | 1.77 | 3.32 | .17 | 3.14 |
| 25+ | 1-25-79 | 5 | .35 | .75 | .16 | .90 |
| 26≠ | 2-14-79 | 1 | 1.70 | 0 | 0 | .06 |
| 27≠ | 2-22-79 | 2 | 7.62 | 3.94 | .96 | 3.43 |
| 28+ | 2-24-79 | 2 | 1.20 | 11.96 | 3.56 | 9.52 |
| 29+ | 2-27-79 | 6 | 1.54 | 3.17 | 1.23 | 2.59 |

---

*Indicates starting date.

+Runoff values shown may include runoff resulting from the preceding event or events. Duration of the preceding event was likely longer than value shown.

≠Rain values shown are actually snow melt. Runoff on 2/14/79 resulted from 10.5 cm snow which occurred 2/9/79. Runoff which began 2/22/79 resulted from 25 cm snow which occurred 2/18/79.

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Individual subsurface runoff events ranged from one to eight days. As samples were collected only once daily, an event which ranged from 0 to 24 hours was recorded as a one-day event.

Subsurface runoff was consistently higher on the high-rate treatment (plot 4), slightly lower on the low-rate treatment (plot 6), and substantially lower on the medium-rate treatment (plot 5). Plot 6 recorded an average of 77% and plot 5 an average of 21% as much subsurface runoff as plot 4. While plot 4 received two and four times as much lagoon effluent as plots 5 and 6, respectively, the difference in subsurface runoff was not a direct consequence of the different irrigation volumes as 80% of all subsurface runoff occurred during nonirrigation. Furthermore, 70% of the runoff during non-irrigation occurred during January, February and March when irrigation should have no effect on runoff. The observed differences in runoff volume between plots 4 and 6 could result from differences in the plot soil physical properties such as basic soil structure, surface storage, hydraulic conductivities and the relative difference between the conductivity in the A and B horizon which would influence the proportions of rainfall which became lateral flow and deep seepage. In addition, the observed differences could result from basic sampling errors such as improper drain tube installation at the clay interface, inadequate restrictions of water movement within plots and between plots by the plastic barrier, and the inaccuracy of the tipping bucket apparatus. The extremely low runoff volumes observed on plot 5 were not likely a result of different soil properties, but rather equipment installation. In addition to the previous explanations, the drain tube on plot 5 was installed against the natural gradient of the clay layer. Therefore, it was necessary to backfill the upslope end to produce the proper gradient towards the sampling apparatus. The line may have settled, reducing the flow gradient, thus allowing sediment to fill and block the line which would likely increase seepage into the clay layer around the tile and to surrounding areas. Piezometers were installed in March 1978 near the tile lines to measure water table heights above the lines. The upslope end of plot 5 did show a higher water table height following heavy rainfall; however, the data was insufficient to conclude that the drain tube was restricting flow.

For the 20-month period, subsurface runoff accounted for 35.66, 7.65, and 27.36% of the total rainfall on plots 4, 5 and 6, respectively. With the inclusion of irrigation, subsurface runoff accounted for 25.43, 6.45 and 25.35% of the total rainfall plus irrigation on plots 4, 5 and 6, respectively. Plots 4 and 6 fell well within the range of 16 to 32% observed by Jackson et al. (1973) for a similar soil in the Georgia Coastal Plains. Thus, this strongly suggests that the low volumes observed on plot 5 were, in fact, due to the inadequacy of the sampling equipment to confine and accurately measure flow within this plot. Therefore, to determine the mass movement in subsurface flow and to estimate the total mass balance for the system, the observed volume on plot 5 was neglected and the volume used in further study was estimated as an average of the observed volumes on plots 4 and 6, Table 46.

TABLE 46. MONTHLY SUBSURFACE RUNOFF, JULY 1, 1977 - FEBRUARY, 1979

| Month | Year | Runoff volume, cm[†]<br>High (Plot 4) | Med (Plot 5) | Low (Plot 6) | Estimated medium[*] |
|---|---|---|---|---|---|
| July | 1977 | 0 | 0 | 0 | 0 |
| August | | 0 | Trace | Trace | 0 |
| September | | 2.59 | 1.26 | .87 | 1.73 |
| October | | .04 | .04 | .04 | .04 |
| November | | 3.73 | .81 | 3.41 | 3.56 |
| December | | .01 | .02 | .02 | .02 |
| January | 1978 | 17.30 | 3.10 | 11.90 | 14.60 |
| February | | .03 | 0 | Trace | 0 |
| March | | 5.04 | .91 | 4.68 | 4.86 |
| April | | 5.87 | 1.04 | 5.33 | 5.60 |
| May | | 9.22 | 1.20 | 5.56 | 7.39 |
| June | | 3.40 | .73 | 2.54 | 2.97 |
| July | | .76 | .01 | .02 | .38 |
| August | | 0 | 0 | 0 | 0 |
| September | | 0 | 0 | 0 | 0 |
| October | | 0 | 0 | 0 | 0 |
| November | | 0 | 0 | 0 | 0 |
| December | | 0 | 0 | 0 | 0 |
| January | 1979 | 4.07 | .39 | 4.62 | 4.34 |
| February | | 18.10 | 5.50 | 14.87 | 16.49 |
| March | | 0.96 | 0.25 | 0.73 | 0.84 |
| Total | | 71.16 | 15.26 | 54.60 | 62.82 |

[†] When a runoff event continued into the next month, it was divided so that volumes listed are actual runoff volumes measured for the calendar month.

[*] Estimated subsurface runoff for the medium rate treatment is the arithmetic average of the low and high rate treatments.

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## Correlation Between Subsurface Runoff and Rainfall

Results of linear regression models evaluated for all rainfall events, and just those rainfall events which had subsurface runoff, indicated that there was very little correlation between rainfall and subsurface runoff. Correlation coefficients for both models were less than 0.2 on all plots. An additional regression model was evaluated for rainfall events which had subsurface runoff during the non-irrigation season (80% of all subsurface runoff occurred during non-irrigation). This model yielded a better correlation between rainfall and subsurface runoff; however, correlation coefficients for this model did not exceed 0.35. As runoff (both surface and subsurface) is dependent on antecedent moisture at the time the rainfall event occurs, a regression model was evaluated which indirectly reflected antecedent moisture. The model evaluated the influence of monthly moisture excess (rainfall + irrigation - evapotranspiration) on subsurface runoff. Correlation coefficients for this model ranged from 0.39 to 0.42.

The results of all linear regression models indicated that factors in addition to rainfall amount imposed a significant influence on susbsurface runoff. Such factors could include plot storage within the A horizon at the time the rainfall event occurred, rainfall intensity and the relative hydraulic conductivity between the A and B horizon.

## Influence of Surface Storage and Irrigation on Subsurface Runoff

The soil-water characteristics for undisturbed soil cores were measured with the pressure plate apparatus (Hillel, 1971). From the results of this study, the potential difference in subsurface storage (A horizon) and the potential difference in subsurface runoff from plots 4 and 6 were determined, Table 47. Of the 29 runoff events which occurred, nine events were considerably less than the potential difference in surface storage (0.38 cm) and were eliminated. In addition, because of the low runoff values observed on plot 5, those values were also omitted. As the maximum potential difference in surface storage would not be attained at the beginning of each rainfall event, an arithematic average of the minimum difference (0 in the case of continuous flow) and maximum difference was used to determine the potential difference in subsurface flow.

After reducing the runoff volume on plot 4 during the non-irrigation season by an amount believed due to the potential difference in surface storage, the remaining difference was determined and attributed to variation in soil structure, relative difference in the A and B horizon hydraulic conductivities, sampling technique, and equipment error (none of which were measured). Then assuming the same relative variation or error during the irrigation season, the subsurface runoff on plot 4 influenced by the higher irrigation rate was determined. This runoff did not directly result from irrigation, as all subsurface flow was associated with a rainfall event, but rather was induced by irrigation which increased soil moisture and reduced potential surface storage.

## TABLE 47. DIFFERENTIAL SUBSURFACE RUNOFF BETWEEN PLOTS

| Category | Number of events[+] | Runoff, cm |  |  | Amount of runoff difference attributed to plot differences, cm |  |  |
|---|---|---|---|---|---|---|---|
|  |  | High (Plot 4) | Low (Plot 6) | Difference | Soil water storage[*] | Soil hydraulic properties | Irrigation volume |
| During non-irrigation season | 14 | 55.81 | 45.83 | 9.98 | 2.66 | 7.32 | — |
| During irrigation season | 6 | 15.27 | 8.49 | 6.78 | 1.14 | 1.35[≠] | 4.29 |
| Total | 20 | 71.08 | 54.32 | 16.76 | 3.80 | 8.67 | 4.29 |

[+] Only the 20 events when at least one plot had runoff greater than 0.15 cm were considered out of the total of 29 events.

[*] Potential water storage amounts in the A horizon were 11.94 cm and 12.32 cm for plot 4 and plot 6, respectively. Difference in storage between plot 4 and plot 6 at the start of each event was assumed to be equal to 0.19 cm, which is average of minimum (0 cm) and maximum (0.38 cm) potential difference.

[≠] Value shown represents the same percentage of plot 6 runoff during irrigation season as occurred during non-irrigation season.

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## CONCENTRATIONS IN SUBSURFACE RUNOFF

A constant fraction of subsurface drainage flow was collected for each runoff event and analyzed for COD, TOC, TKN, $NO_3$-N, P and $Cl^-$. In order to more easily determine the effects of nutrient loading rate and season, monthly mean concentrations were calculated by dividing total mass by total runoff volume for each month, and these are shown in Figures 21-26. No runoff was measured August 1978 through December 1978, and thus no concentration data is shown. Some other months had less than 0.05 cm runoff from one or more plots, and these months often had some of the highest concentration values. Examples are August, October and December in 1977 and February and July in 1978. When considering seasonal and treatment effects, neglecting these months with low runoff volumes usually results in less variable concentration and thus smoother trends.

Parameters which would be expected to remain relatively constant in subsurface runoff are COD, TOC and TKN. Organic matter and $NH_4^+$ should be absorbed by the soil in the A horizon and not readily move with drainage water. Except for some months with low runoff (particularly October and December 1977 and February 1978), monthly mean concentrations of COD, TOC and TKN (Figures 21-23) were nearly the same for all treatments (loading rates) for any particular parameter and month. The concentrations of all three parameters showed some general trends of decreasing from November 1977 to March 1978 and then increasing from March 1978 to June 1978, particularly when months with low runoff are neglected. These trends may be in response to the irrigation season ending about October and starting again in April. Also, the seasonal temperature changes and the related changes in soil organic matter mineralization may affect these trends. Because there was no runoff in the fall of 1978, the 1978 seasonal trends in concentrations for fall and early winter cannot be compared to 1977. However, runoff volumes for January 1978 and February 1979 were similar and monthly mean concentrations were similar. Overall, the range of monthly mean concentrations for all three treatments for months with runoff greater than 0.1 cm were about 15-60 mg/l for COD, 5-20 mg/l for TOC and 1-3 mg/l for TKN.

Monthly mean concentrations of P (Figure 24) were generally higher and more variable for the high-rate treatment. Concentrations for the medium rate and low-rate treatments for months with runoff greater than 0.1 cm were usually in the range of 0.1 to 0.3 mg/l while concentrations on the high-rate treatment were usually in the range of 0.3 to 1 mg/l. The main exception was for June 1978 when runoff was greater than 2.5 cm on all plots and concentrations were in the range of about 1 to 2 mg/l for the three treatments. A possible explanation for the generally higher concentrations in June 1978 was the high rainfall, which was 13.0 cm, and a higher-than-usual irrigation rate in May and June because of delay in starting irrigation in 1978. This high rainfall combined with irrigation could have promoted leaching of P in the soil or downward movement of P in the irrigated effluent. Other parameters not readily leached (COD, TOC, and TKN) also had a peak in June 1978. Because there was no runoff August - December 1978, trends from late summer to early winter cannot be compared for the two years, but concentrations were similar in the period January - March during both

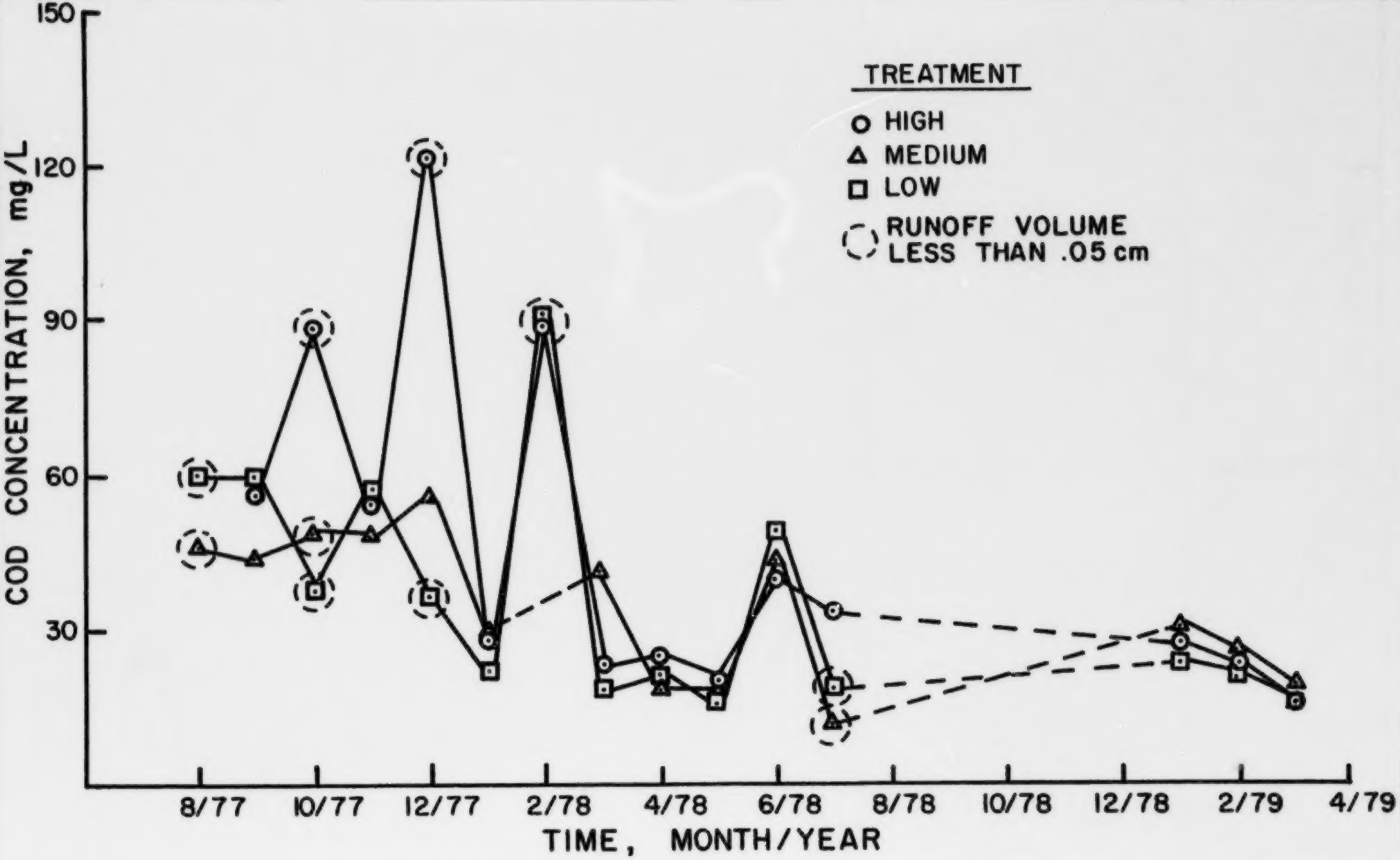

Figure 21. Monthly flow weighted average COD concentration in subsurface runoff. (Broken line indicates no runoff).

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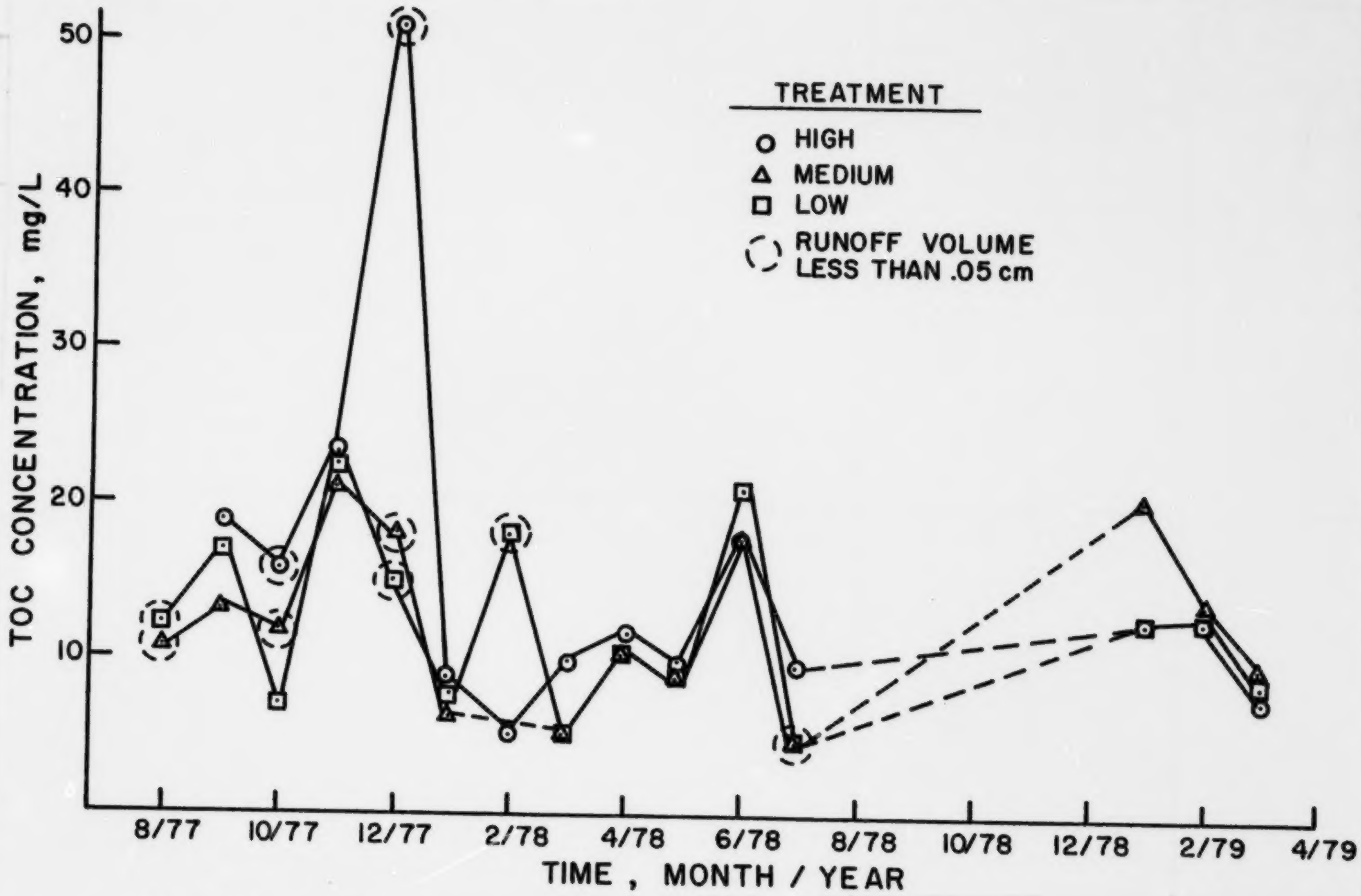

Figure 22. Monthly flow weighted average TOC concentration in subsurface runoff. (Broken line indicates no runoff).

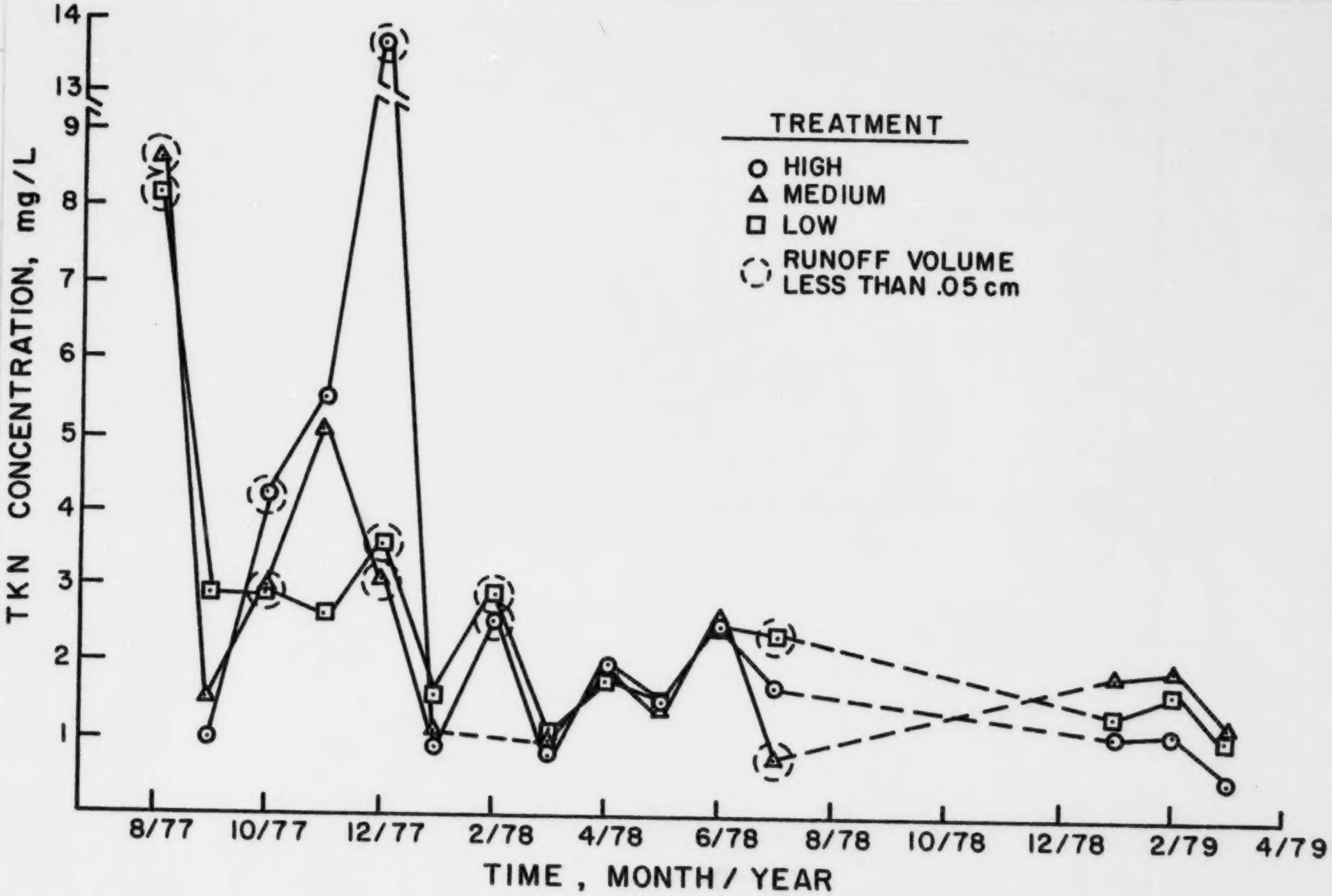

Figure 23. Monthly flow weighted average TKN concentration in subsurface runoff. (Broken line indicates no runoff).

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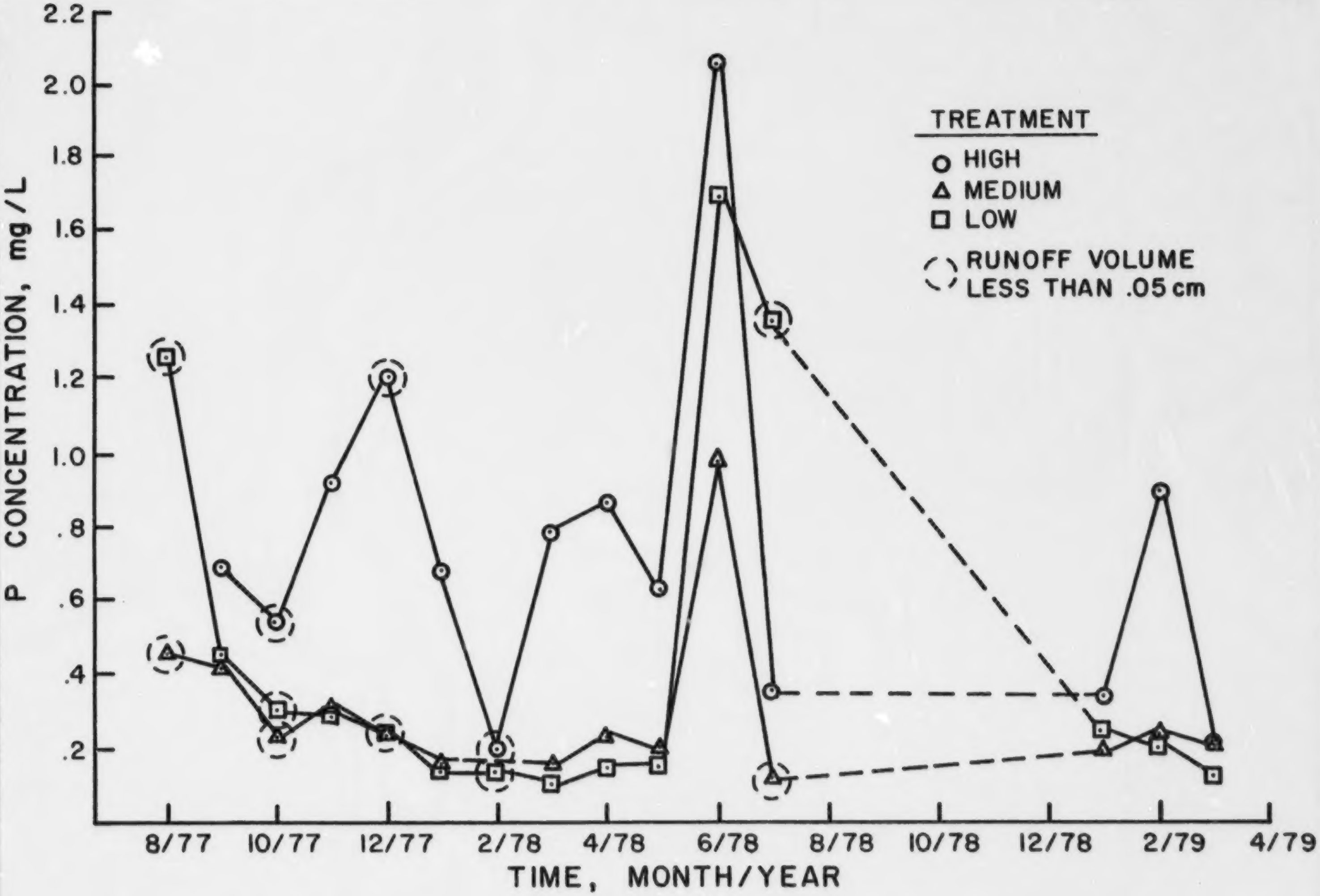

Figure 24. Monthly flow weighted average P concentration in subsurface runoff. (Broken line indicates no runoff).

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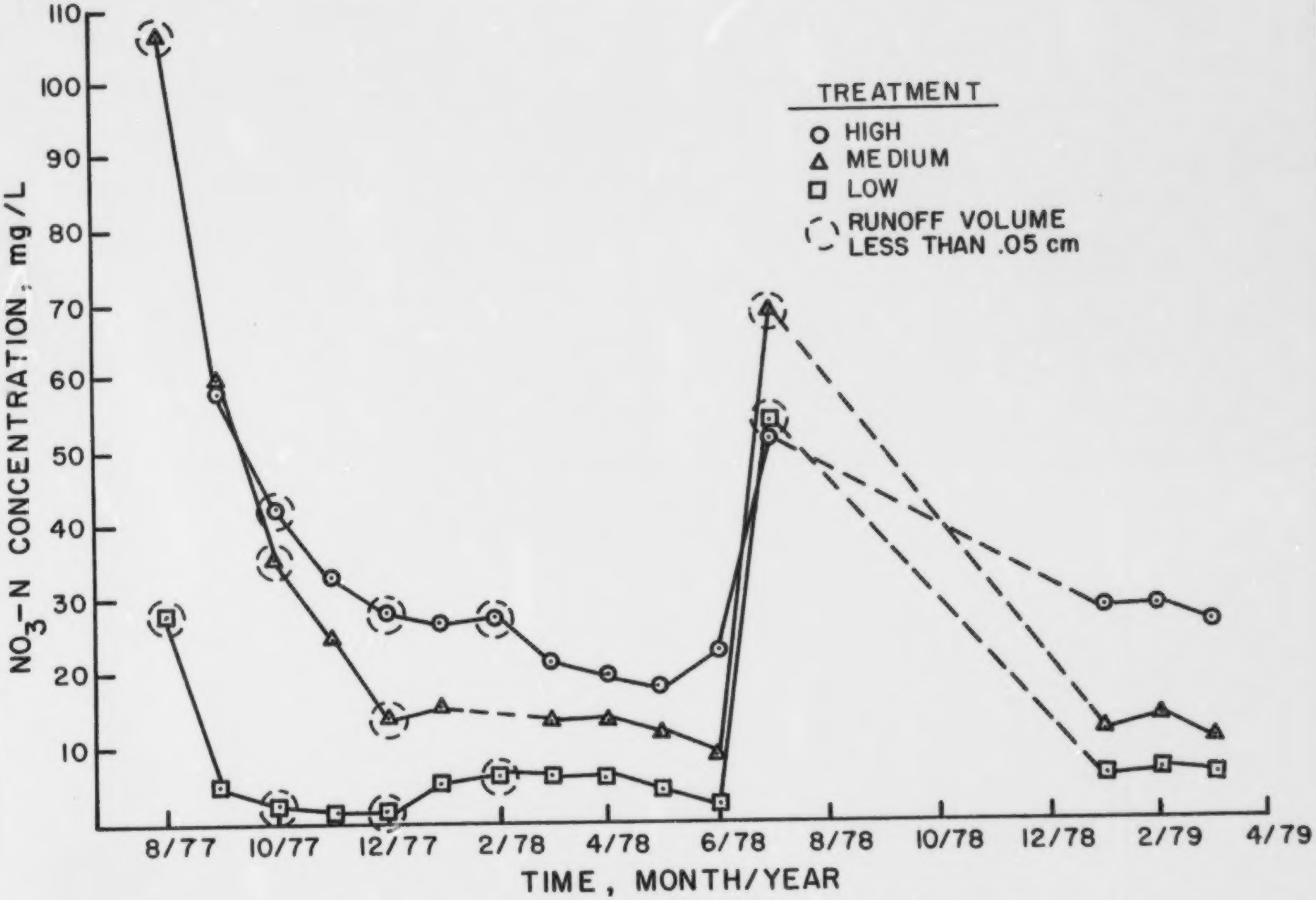

Figure 25. Monthly flow weighted average $NO_3$-N concentration in subsurface runoff. (Broken line indicates no runoff).

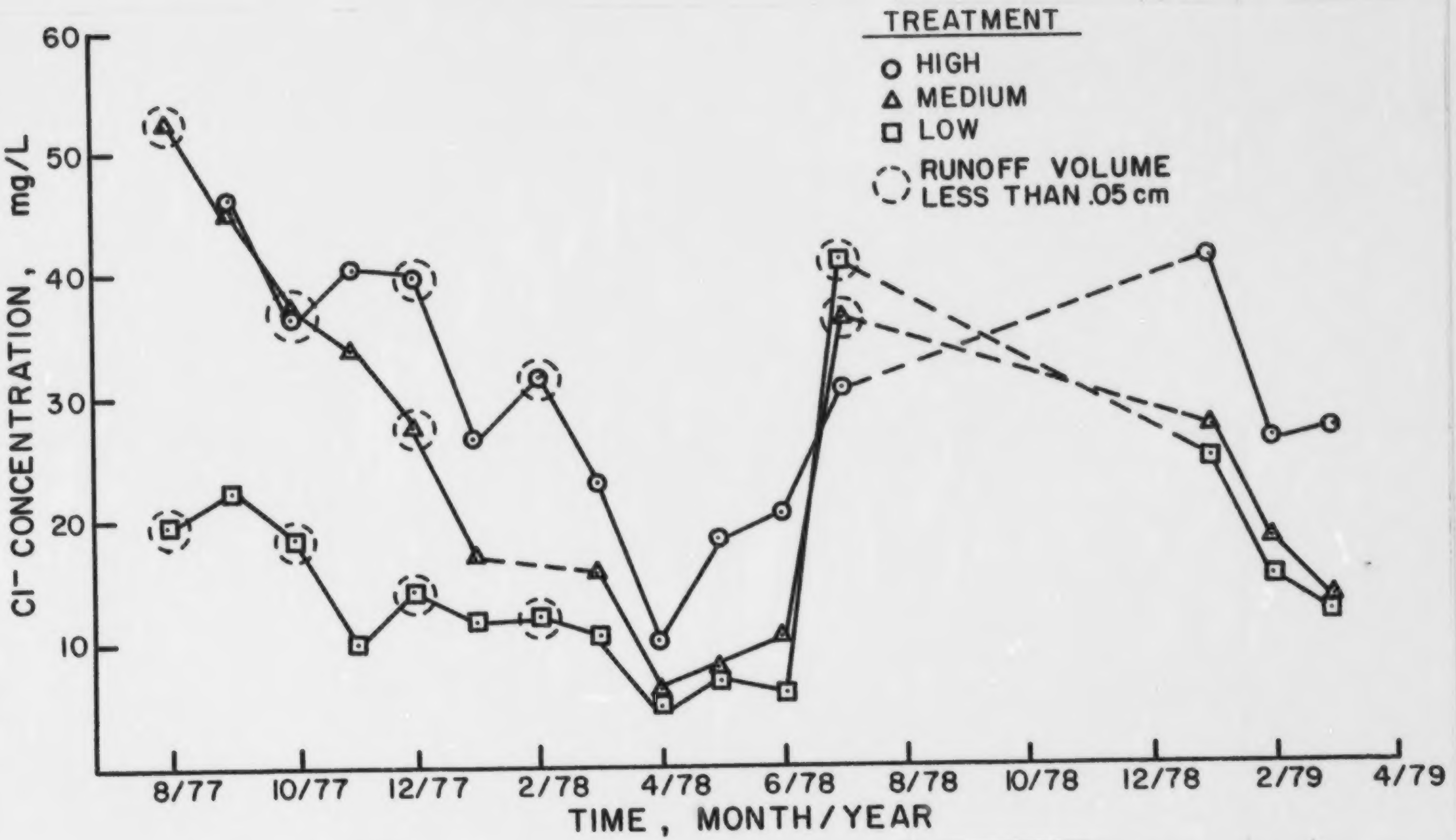

Figure 26. Monthly flow weighted average $Cl^-$ concentration in subsurface runoff. (Broken line indicates no runoff).

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years. Overall, the high-rate treatment had high concentrations which indicated that P was moving with subsurface flow.

$NO_3$-N and $Cl^-$ had similar trends in monthly mean concentrations (Figures 25 and 26). The mean of the monthly concentrations were significantly higher (at 5% level) for the high-rate treatment for both $NO_3$-N and $Cl^-$. Months with low runoff sometimes had very high concentrations, e.g. August 1977 and July 1978. $NO_3$-N and $Cl^-$ concentrations had a gradual decline after the irrigation season ended in 1977. Because of lack of runoff in August - December 1978 this trend of declining concentrations after the irrigation season was not as evident the second year, but did appear similarly in January - March during both years. Essentially, the $NO_3$-N levels in the A horizon increased during the irrigation season because of the N application in effluent, and terminating irrigation near the end of the growing season allowed for reductions in N levels during the non-growing season by leaching of $NO_3$-N.

The decline in $NO_3$-N concentration after the irrigation season was gradual, and this indicated that perhaps (1) the residual $NO_3$-N in the soil was not flushed as a pulse flow, possibly because of how water moved through the soil, and/or (2) residual organic N continued to mineralize to $NH_4^+$ and to $NO_3^-$ after irrigation ceased and this resulted in a slow release with gradual decline in $NO_3^-$. For some runoff events of several days, more than one sample was taken. Comparing concentrations for different days within the event, the pulse flow phenomena was not observed. Concentrations remained fairly constant (usually within 10%) throughout the duration of the event, and sometimes even increased during the event. Thus, the movement of $NO_3^-$ to drainage water was fairly constant for any one event. This could result partly from how $NO_3^-$ was distributed in soil pore spaces of different sizes and how water moved through the pore spaces.

The drinking water standard for $NO_3$-N is normally 10 ppm. Monthly mean concentrations for subsurface flow from the medium-rate and high-rate treatments were usually well above 10 ppm. Thus, this flow would tend to degrade streams and shallow groundwater into which it flowed. The relative impact of this subsurface flow on water quality would depend mainly upon dilution ratios and denitrification rates. To reduce the $NO_3$-N concentration before reaching a stream, a buffer area could be utilized, but in many land application systems or farming situations land area is a limiting factor. Also, a large buffer area would probably be required when $NO_3$-N concentrations are 20 to 30 ppm. Therefore, the normal solution to keeping subsurface water $NO_3$-N levels below 10 ppm is to apply N at rates close to the rate of crop utilization.

Summarizing the concentration data, the most evident effects of various lagoon effluent application rates were the high concentrations of $NO_3$-N and $Cl^-$ for the medium-rate and high-rate treatments, and the high P concentration for the high-rate treatment. There were some trends in concentration change which seemed to result from the management schedule which had irrigation of lagoon effluent only during the growing season (usually April - September), but lack of runoff during several months tended to confuse trends. Concentrations of most parameters tended to be lowest in the period January - March each year, but this was also the period when most subsurface flow occurred.

## MASS TRANSPORT IN SUBSURFACE RUNOFF

Mass transport in subsurface runoff from plots 4, 5 and 6 for the period July 1977 through February 1979 is shown in Table 48 for six constituents. As expected, the constituent yield generally increased as the effluent application rate increased. Based on analysis of variance of yields from all runoff events, the mean yields were significantly different (at 5% level) for all treatments for $NO_3$-N and $Cl^-$, which was not surprising because $NO_3$-N and $Cl^-$ move readily with water. In addition, the increase in P yield was also significant on the high-rate treatment, which further emphasized that P, when applied in excess of the soil assimilatory capability, will move with soil water. Treatment means were not significantly different (at 5% level) for COD, TOC, and TKN. Nutrient yields in subsurface runoff, surface runoff, and harvested forage will be compared later in this report when a mass balance is presented.

TABLE 48. NUTRIENT YIELD IN SUBSURFACE RUNOFF, JULY 1977 - FEBRUARY 1979

| Nutrient | Nutrient yield, kg/ha[*] | | |
|---|---|---|---|
| | High (Plot 4) | Medium (Plot 5) | Low (Plot 6) |
| COD | 200.5 | 181.0 | 140.0 |
| TOC | 61.1 | 50.3 | 43.8 |
| TKN | 10.5 | 11.0 | 9.2 |
| $NO_3$-N | 192.9a | 100.2b | 31.1c |
| P | 5.7a | 1.6b | 1.4b |
| $Cl^-$ | 182.8a | 109.2b | 67.7c |

[*] Where values are followed by same lower case letter mean yields of all runoff events were not significantly different at the 5 percent level of significance.

In order to calculate a mass balance for selected nutrients, the period of data for mass transport in subsurface runoff needed to correspond to the periods of data for nutrient application and crop removal. Because subsurface runoff measurements began in the middle of an irrigation and crop-growing season, it was necessary to estimate the nutrient loss in subsurface runoff for the period March 1, 1977 to July 1, 1977 so that the subsurface data could be extrapolated to include a two-year study period (Table 49). Also, this would allow comparison of annual trends for March 1 to March 1.

## TABLE 49. ANNUAL NUTRIENT YIELD IN SUBSURFACE RUNOFF

| Year | Nutrient yield, kg/ha/yr* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TKN | | | P | | | $NO_3$-N | | | $Cl^-$ | | |
| | P4§ | P5 | P6 | P4 | P5 | P6 | P4 | P5 | P6 | P4 | P5 | P6 |
| March 1977 –+<br>Feb. 1978 | 7.06 | 5.67 | 4.47 | 3.43a | 0.81b | 0.66b | 112.06a | 57.27b | 12.49c | 105.85a | 57.03b | 26.32c |
| March 1978–<br>Feb. 1979 | 6.52 | 7.32 | 6.25 | 4.01a | 1.18b | 1.07b | 118.47a | 58.00b | 23.44c | 109.79a | 64.04b | 48.07b |
| Average | 6.79 | 6.50 | 5.36 | 3.72a | 1.00b | 0.87b | 115.27a | 57.64b | 17.97c | 107.82a | 60.54b | 37.20b |

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[*] For the period March 1, 1977 to July 1, 1977, no data was collected as equipment was being installed. Runoff volume was estimated as Runoff 1977 = (Runoff 1978) (Excess 1977)/(Excess 1978) where

Runoff 1978 = Subsurface runoff measured from March 1, 1978 to July 1, 1978
Excess 1977 = Rainfall + irrigation - ET from March 1, 1977 to July 1, 1977
Excess 1978 = Rainfall = irrigation - ET from March 1, 1978 to July 1, 1978

Nutrient yield for the period March 1, 1977 to July 1, 1977 was then estimated by multiplying the flow-weighted average monthly concentration for 1978 by the estimated volume for 1977.

[+] Where values for each parameter are followed by the same lower case letter, mean yields of all runoff events were not significantly different at the 5 percent level of significance.

[§] P4, P5, P6 are plots 4, 5, and 6, respectively.

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The nutrient yield for most parameters was slightly higher the second year of the study, but this was not considered an accumulative effect of lagoon effluent application as runoff volume was also higher during the second year. In addition, nutrient concentrations in subsurface runoff for those months which had runoff in both years were about equal. Comparing treatment means of runoff events by year and for both years after the data was extrapolated to include March 1 through July 1, 1977, the significant treatment differences were the same as for the 20-month period except that $Cl^-$ did not show a significant difference between the low-rate and medium-rate treatment for the second year and for the two-year period.

After the subsurface runoff nutrient yield data was extrapolated to cover two years, regression analysis was performed to determine the relationship between annual nutrient yield in subsurface runoff and the annual amount of nutrient applied, as well as the annual runoff volume (Table 50). The analysis showed that the level of $NO_3$-N and P transported in subsurface runoff was highly dependent upon the level of nutrient applied, while TKN was dependent on runoff volume, and $Cl^-$ was dependent upon the runoff volume and amount applied. However, when using the annual yields for comparisons or regressions, the results are somewhat biased because of estimating yields for March 1, 1977 to July 1, 1977 using data for these months from 1978.

## MASS BALANCE FOR SELECTED NUTRIENTS - ALL IRRIGATED PLOTS

The mass balance for selected nutrients consisted of accounting for inputs, accumulation in the soil, and amounts removed by crop harvest and rainfall surface runoff. The mass balance results were tabulated for each effluent loading rate for the period 1974-1978 using mean values of the three land replications (Table 51 to 53). Surface runoff losses were for the calendar year whereas soil accumulation was determined as the difference in soil reserves from one fall sampling to the next. However, surface runoff losses were usually negligible compared to soil accumulation and crop uptake, and the fall soil sampling was usually in November or December. Two reference compartments or soil volumes were used in the mass balance -- the upper 75 cm of the soil profile for the period 1974-1975 and the upper 215 cm of the soil profile for the period 1976-1978.

The nutrients which were included were total N (TKN + $NO_3$-N), P and K, and $Cl^-$ in 1978 only. The amount of nutrient (Tables 51-53) removed via each pathway increased as the loading rate increased. In addition, the amount of material which was not accounted for also increased as the loading rate increased. (The difference between input and accounted-for amounts of the various parameters was termed unaccounted-for material.) Results were variable, but on the average about 100% of the applied P and K and 70% of the applied N was accounted for on the low-rate treatment (Table 54), mainly by crop uptake and soil accumulation because loss in surface runoff was usually minor compared to crop uptake and soil accumulation. Unaccounted-for material on the medium-rate and high-rate treatments were on the average about 20 and 40% of the amounts applied, respectively, for P and K and about 40 and 65% of applied for N (Table 54). In addition, unaccounted-for N on the high-rate exceeded the applied amount on the medium-rate treatment.

## TABLE 50. REGRESSION EQUATIONS FOR SUBSURFACE RUNOFF MASS YIELDS

| Constituent | Equation[+] | Significant dependent variable | Correlation coefficient, r |
|---|---|---|---|
| TKN | $Y = -\ 0.0005\ X_1 + 0.12\ X_2 + 1.80$ | Runoff volume * | 0.91 |
| $NO_3$-N[≠] | $Y = 0.0904\ X_1 + 0.84\ X_2 - 27.94$ | N applied ** | 0.99 |
| P | $Y = 0.0115\ X_1 + 0.04\ X_2 - 1.47$ | P applied * | 0.95 |
| $Cl^-$ | $Y = 0.0986\ X_1 + 1.42\ X_2 - 22.15$ | $Cl^-$ applied ***<br>Runoff volume ** | 0.99 |

[+] Y = nutrient yield, kg/ha/yr: $X_1$ = nutrient application rate, kg/ha/yr: $X_2$ = runoff volume, cm/yr. Annual period is March 1 - March 1.

[≠] $X_1$, nutrient applied = TKN.

* Significant at 95% level<br>
**Significant at 99% level<br>
***Significant at 99.9% level.

## TABLE 51. NUTRIENT MASS BALANCE - LOW-RATE TREATMENT

| Year | Nutrient | Applied effluent | Crop[ǂ] uptake | Surface runoff | Soil[*] accumulation | Accounted for: Amount | Accounted for: % of applied | Unaccounted for |
|---|---|---|---|---|---|---|---|---|
| | | Annual input, output, and accumulation, kg/ha[§] | | | | | | |
| 1974 | N | 398 | 278 | 7.7 | 8 | 294 | 74 | 104 |
| | P | 74 | 29 | 2.1 | 68 | 99 | 134 | -25 |
| | K | 405 | 268 | 14.0 | 199 | 481 | 119 | -76 |
| 1975 | N | 429 | 274 | 5.2 | 9 | 288 | 67 | 141 |
| | P | 90 | 38 | 3.3 | -6 | 35 | 39 | 55 |
| | K | 411 | 246 | 7.5 | 38 | 292 | 71 | 119 |
| 1976 | N | 297 | 199 | 7.0 | -10 | 196 | 66 | 101 |
| | P | 88 | 39 | 2.2 | 81 | 122 | 139 | -34 |
| | K | 304 | 214 | 7.1 | 67 | 288 | 95 | 16 |
| 1977 | N | 351 | 248 | 1.9 | 13 | 263 | 75 | 88 |
| | P | 89 | 37 | 0.8 | 118 | 156 | 175 | -67 |
| | K | 209 | 220 | 2.8 | 68 | 291 | 139 | -82 |
| 1978 | N | 260 | 225 | 4.6 | -23 | 207 | 80 | 53 |
| | P | 59 | 31 | 1.5 | -46 | -14 | -23 | 73 |
| | K | 163 | 195 | 0.8 | 27 | 223 | 137 | -60 |
| | Cl$^{-}$[+] | 142 | 72 | 1.9 | 353 | 427 | 300 | -285 |
| Mean 1974 - 1978 | N | 347 | 245 | 5.3 | - 1 | 250 | 72 | 97 |
| | P | 80 | 35 | 2.0 | 43 | 80 | 93 | 0 |
| | K | 298 | 229 | 6.4 | 80 | 315 | 112 | -17 |

[§] Average of three replications.

[*] The reference volume for soil accumulation was the upper 75 cm of the profile for 1974 and 1975 and the upper 215 cm of the profile for 1976-1978.

[+] Soil Cl$^{-}$ was measured only in 1978.

[ǂ] Crop uptake for 1974, 1975 and 1976 were estimated by multiplying annual yield by arithmetic mean concentrations of harvests whereas uptake for 1977 and 1978 was calculated by harvest and summed

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## TABLE 52. NUTRIENT MASS BALANCE - MEDIUM-RATE TREATMENT

| | | Annual input, output, and accumulation, kg/ha | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Accounted for | | |
| Year | Nutrient | Applied effluent | Crop ‡ uptake | Surface runoff | Soil* accumulation | Amount | % of applied | Unaccounted for |
| 1974 | N | 795 | 456 | 18.8 | 55 | 530 | 67 | 265 |
| | P | 148 | 39 | 1.6 | 95 | 136 | 92 | 12 |
| | K | 815 | 389 | 19.6 | 188 | 597 | 73 | 218 |
| 1975 | N | 858 | 456 | 8.6 | -7 | 458 | 53 | 400 |
| | P | 179 | 53 | 1.8 | 82 | 137 | 76 | 42 |
| | K | 823 | 392 | 6.1 | 105 | 503 | 61 | 320 |
| 1976 | N | 598 | 402 | 1.2 | 53 | 456 | 76 | 142 |
| | P | 177 | 59 | 0.5 | 108 | 168 | 95 | 9 |
| | K | 598 | 380 | 2.5 | 190 | 573 | 96 | 25 |
| 1977 | N | 581 | 305 | 3.4 | 8 | 316 | 54 | 265 |
| | P | 144 | 37 | 2.7 | 190 | 230 | 160 | -86 |
| | K | 346 | 241 | 2.6 | 48 | 292 | 84 | 54 |
| 1978 | N | 597 | 347 | 20.0 | -90 | 277 | 46 | 320 |
| | P | 136 | 41 | 7.2 | -122 | -74 | -54 | 210 |
| | K | 376 | 283 | 6.7 | 155 | 445 | 118 | -69 |
| | $Cl^-$ + | 325 | 95 | 8.2 | 295 | 398 | 122 | -73 |
| Mean 1974-1978 | N | 686 | 393 | 10.4 | 4 | 407 | 59 | 278 |
| | P | 157 | 46 | 2.8 | 71 | 119 | 74 | 37 |
| | K | 592 | 337 | 7.8 | 137 | 482 | 86 | 110 |

[§] Average of three replications.

[*] The reference volume for soil accumulation was the upper 75 cm of the profile for 1974-1975 and the upper 215 cm of the profile for 1976-1978.

[+] Soil $Cl^-$ was measured only in 1978.

[‡] Crop uptake for 1974, 1975 and 1976 were estimated by multiplying annual yield by arithmetic mean concentrations of harvests whereas uptake for 1977 and 1978 was calculated by harvest and summed to get annual total.

## TABLE 53. NUTRIENT MASS BALANCE- HIGH-RATE TREATMENT

| Year | Nutrient | Annual input, output, and accumulation, kg/ha[§] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Applied effluent | Crop uptake[‡] | Surface runoff | Soil accumulation[*] | Accounted for | | Unaccounted for |
| | | | | | | Amount | % of applied | |
| 1974 | N | 1590 | 464 | 57.7 | 41 | 563 | 35 | 1027 |
| | P | 296 | 43 | 12.5 | 203 | 259 | 88 | 37 |
| | K | 1631 | 398 | 67.2 | 305 | 770 | 47 | 861 |
| 1975 | N | 1716 | 613 | 25.7 | 31 | 670 | 39 | 1046 |
| | P | 358 | 71 | 10.5 | 86 | 168 | 47 | 190 |
| | K | 1646 | 486 | 19.7 | 224 | 730 | 44 | 916 |
| 1976 | N | 1075 | 522 | 15.1 | 113 | 650 | 60 | 425 |
| | P | 310 | 72 | 6.9 | 404 | 483 | 156 | -173 |
| | K | 1072 | 464 | 12.6 | 319 | 796 | 74 | 276 |
| 1977 | N | 1223 | 288 | 9.6 | -8 | 290 | 24 | 933 |
| | P | 294 | 39 | 5.0 | 378 | 422 | 144 | -128 |
| | K | 712 | 243 | 7.8 | 445 | 696 | 98 | 16 |
| 1978 | N | 1234 | 410 | 8.5 | -104 | 314 | 25 | 920 |
| | P | 278 | 53 | 4.4 | -386 | -329 | -118 | 607 |
| | K | 778 | 308 | 1.6 | -97 | 213 | 27 | 565 |
| | $Cl^-$[+] | 665 | 98 | 7.7 | 143 | 249 | 37 | 416 |
| Mean 1974-1978 | N | 1368 | 459 | 23.3 | 15 | 497 | 37 | 870 |
| | P | 307 | 56 | 7.9 | 137 | 201 | 63 | 107 |
| | K | 1167 | 380 | 21.8 | 239 | 641 | 58 | 527 |

[§] Average of three replications.

[‡] Crop uptake for 1974, 1975 and 1976 were estimated by multiplying annual yield by arithmetic mean concentrations of harvests whereas uptake for 1977 and 1978 was calculated by harvest and summed to get annual total.

[*] The reference volume for soil accumulation was the upper 75 cm of the profile for 1974-1975 and the upper 215 cm of the profile for 1976-1978.

[+] Soil chloride was measured only in 1978.

## TABLE 54. NUTRIENT MASS BALANCE SUMMARY -- 1974 - 1978*

| Treatment | N | P | K |
|---|---|---|---|
| | Amount of element applied, kg/ha/yr | | |
| Low | 347 ± 70 | 80 ± 13 | 298 ± 112 |
| Medium | 686 ± 130 | 157 ± 20 | 592 ± 229 |
| High | 1,368 ± 272 | 307 ± 31 | 1,167 ± 450 |
| | Accounted for as % of applied + | | |
| Low | 72 ± 6 | 93 ± 82 | 112 ± 29 |
| Medium | 59 ± 12 | 74 ± 78 | 86 ± 22 |
| High | 37 ± 15 | 63 ± 110 | 58 ± 28 |
| | Amount unaccounted for, kg/ha/yr ≠ | | |
| Low | 97 ± 32 | 0 ± 60 | -17 ± 85 |
| Medium | 278 ± 94 | 37 ± 108 | 110 ± 157 |
| High | 870 ± 255 | 107 ± 314 | 527 ± 384 |

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* Summary of average values of annual amounts in Tables 51, 52, and 53, with standard deviation.

+ Accounted for as crop uptake, surface runoff transport or change in soil reserves.

≠ Difference between amount applied and amount accounted for in above-mentioned items.

Unaccounted-for material at each level of treatment could be attributed to lateral movement along the interface of the A-B horizon, leaching below the A horizon or losses to soil states not evaluated by the analytical methods used. In a later section of this report, lateral transport and leaching of nutrients will be estimated for plots 4, 5 and 6 for the period of subsurface flow data.

$Cl^-$ was only measured in 1978 and the accumulation in the soil exceeded amounts applied at the low-rate and medium-rate treatments. Also the level of accumulation from April to October in 1978 increased as the loading rate decreased. Since $Cl^-$ is highly soluble and mobile in soil solution, it did not appear likely that it was held by the soil undetectable at one sampling date and then released by the next. Thus, it seems likely that $Cl^-$ measurements were in error on one or both sampling dates.

Overall, the mass balance data was often variable from year to year, particularly the soil accumulation data. Nevertheless, comparison of the treatments indicated that as loading rate increased, greater amounts of nutrients were unaccounted for, which likely meant that greater amounts of nutrients were being transported in lateral and downward subsurface flow. The amount of N unaccounted for on the high-rate treatment was on the average greater than the amount applied on the medium-rate treatment. Unless there is considerable denitrification occurring much N is being transported in subsurface flow.

## MASS BALANCE FOR PLOTS 4, 5, AND 6

Because subsurface runoff data was obtained on plots 4, 5, and 6 for the period July 1977 through February 1979, a mass balance could be calculated to include subsurface transport for these plots for this period. However, since the irrigation and crop-growing season began in April and spring soil sampling in 1977 was in April, the subsurface runoff data had to be estimated for April 1977 - June 1977 to have all inputs to the mass balance for the period April 1977 - February 1979. Also, by estimating subsurface flow for March 1977 - June 1977, the water balance could be calculated for a 2-year period (March 1, 1977 - March 1, 1979). By including subsurface flow in the mass balance for the A horizon the only unknown quantity was the amount leaching into the B horizon. Therefore, the unaccounted-for water was assumed to enter the B horizon, and nutrient transport into the B horizon could be estimated by assuming that nutrient concentrations in subsurface runoff and concentrations in water entering the B horizon were equal.

### Water Balance

The water balance consisted of a monthly comparison of water input (rainfall and irrigation) and pathways for removal or storage (surface runoff, subsurface runoff, ET, and A horizon storage). The reference volume consisted of the upper 75 cm of the soil profile. Evapotranspiration was assumed equal to a 70-year average value for a location about 40 km northwest of the land receiver plots. Actual ET (AET) was assumed equal to potential ET (PET) as long as surface soil-water storage was not depleted.

Surface storage was estimated as the difference in the soil water content in the A horizon at field capacity and the wilting point. Subsurface runoff data included estimates of runoff for the period March 1977 - June 1977 (Table 49). Unaccounted-for water was assumed to be lost to the B horizon by vertical leaching.

A two-year summary of the water balance is shown in Table 55. The magnitude of accounted-for as well as unaccounted-for water increased as the irrigation rate increased. On the average, unaccounted-for water which was assumed to be leached below the A horizon, was 42, 23, and 17 cm which was 25, 16, and 13% of annual rainfall plus irrigation on the high-, medium-, and low-rate treatments, respectively. As expected, most subsurface flow occurred during the period January - March while leaching occurred from July - December on the high-rate treatment and September - January on the low-rate treatment.

While annual rainfall exceeds evaporation at this location, high ET in the period May-July usually results in a water deficit such that AET is less than PET. However, with weekly irrigation during the period May - September, no water deficit was observed by the water balance and AET was not believed to be severely limited by soil-water storage. In fact, soil water storage based on monthly inputs and outputs was maintained at or near field capacity on the high-rate treatment and only during October 1978 was surface storage totally depleted on the low-rate treatment. It should be noted, however, that a monthly water balance does not account for temporary wet and dry periods during the month; thus, on some occasions AET may have been temporarily limited by soil-water storage and was not detected by the monthly balance.

## Nutrient Movement into the B Horizon

Soil water which moved through the A horizon to the A-B interface either moved vertically into the B horizon or laterally above the clay layer. Soil water movement into the B horizon was estimated from the water balance. Nutrient movement into the B horizon was estimated by assuming that the concentration gradient at the A-B interface was the same in both the vertical and horizontal direction. Thus, as the concentration in the horizontal direction was known (measured in tile flow), nutrient movement into the B horizon could be determined by multiplying the flow-weighted average monthly concentration in the tile flow by the leaching volume as determined by the water balance.

As expected, nutrient movement into the B horizon increased as the loading rate increased (Table 56). The increase reflected both higher leaching volume and higher leachate concentrations as the level of treatment increased. P and TKN movement was low and showed only slight influence of loading rate, particularly at the low and medium rates. For the most part, these constituents were absorbed in the upper B horizon (evidenced from soil core concentration profiles for P). $NO_3$-N and $Cl^-$ differences between treatments were, however, quite pronounced. Relative leaching losses of $Cl^-$ on the three treatments approximated the 1:2:4 application rates, while $NO_3$-N yield more closely approximated the ratio of N applied in excess of

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TABLE 55. WATER BALANCE FOR PLOTS 4, 5 AND 6

| | Plot | Rainfall | Irrigation | ET[*] | Surface runoff | Sub-surface runoff | Change[+] in storage | Unaccounted[‡] for |
|---|---|---|---|---|---|---|---|---|
| | | cm | | | | | | |
| March 1977 - Feb. 1978 | 4 | 126.5 | 45.1 | 84.5 | 1.3 | 42.0 | -1.3 | 45.1 |
| | 5 | 126.5 | 21.7 | 84.5 | 1.0 | 32.2 | 0.2 | 30.3 |
| | 6 | 126.5 | 11.6 | 84.5 | 0.8 | 25.7 | 0.8 | 26.3 |
| March 1978 - Feb. 1979 | 4 | 116.8 | 48.9 | 84.5 | 0.4 | 46.4 | -4.2 | 38.6 |
| | 5 | 116.8 | 22.7 | 84.5 | 0.4 | 41.9 | -3.6 | 16.3 |
| | 6 | 116.8 | 8.8 | 84.0 | 0.7 | 37.4 | -3.4 | 6.9 |
| Two-year annual average | 4 | 121.7 | 47.0 | 84.5 | 0.9 | 44.2 | -2.8 | 41.9 |
| | 5 | 121.7 | 22.2 | 84.5 | 0.7 | 37.1 | -1.7 | 23.3 |
| | 6 | 121.7 | 10.2 | 84.3 | 0.8 | 31.6 | -1.3 | 16.6 |

[*] ET = Evapotranspiration as estimated by a 70-year average for Raleigh, N.C. located about 40 km from land application site.

[+] A negative change represents a net decrease in surface storage during each 1-yr period.

[‡] Unaccounted for water represents the difference between measured input and output and was assumed to move vertically into the B horizon.

TABLE 56. NUTRIENT MOVEMENT INTO THE B HORIZON

| | Amount of nutrient leaching into B horizon, kg/ha/yr* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | P | | | TKN | | | $NO_3$-N | | | $Cl^-$ | | |
| Year | P4§ | P5 | P6 | P4 | P5 | P6 | P4 | P5 | P6 | P4 | P5 | P6 |
| March 1977 - Feb. 1978 | 3.0 | 0.9 | 0.8 | 10.8 | 7.8 | 7.8 | 216 | 116 | 7.5 | 177 | 112 | 44 |
| March 1978 - Feb. 1979 | 1.4 | 0.3 | 0.2 | 5.7 | 2.8 | 0.9 | 157 | 35 | 3.9 | 109 | 47 | 17 |
| Average | 2.2 | 0.6 | 0.5 | 8.2 | 5.3 | 4.3 | 186 | 76 | 5.7 | 143 | 79 | 31 |

*The values shown were determined by multiplying the monthly flow-weighted average concentration in tile flow by the leaching volume as determined by the water balance.

§P4, P5, and P6 are plots 4, 5, and 6, respectively.

crop removal. All values were higher in 1977 than in 1978 which was due to a higher leaching volume during the late summer and fall of 1977 when soil-water concentrations were high. (For the period August - October 1977, 44.4 cm of rainfall occurred as compared to only 12.7 cm of rainfall during the same period in 1978.)

$NO_3^-$ and $Cl^-$ which moved pass the A-B horizon interface were expected to accumulate in the B horizon. However, soil core analysis indicated that this was not the case. Apparently any accumulation in the B horizon was temporary, and when additional soil-water moved into the B horizon, these constituents continued to move through the B horizon to groundwater or moved laterally in the B horizon. Based on the total volume of flow into the B horizon and the total yield of nutrients in this flow, annual flow-weighted average concentrations of $NO_3$-N were 3.5, 33 and 44.5 ppm on the low-, medium-, and high-rate treatments, respectively. Thus, there appeared to be a significant pollution potential at the medium and high application rates which could contaminate groundwater.

## Nutrient Mass Balance

Utilizing the subsurface flow data to calculate nutrient transport in lateral soil water flow and to estimate nutrient transport into the B horizon, nutrient mass balances for N (TKN + $NO_3$-N), $Cl^-$, P, and K were calculated for plots 4, 5, and 6 for the period April 1977 through October 1978 (Tables 57, 58, and 59). This 19-month period was further divided into three periods that corresponded with soil sampling dates so that the periods for mass balances covered two growing seasons and one dormant (winter) period. $Cl^-$ was measured in 1978 only. Two reference compartments or soil volumes were used in the balance: (1) the upper 75 cm of the soil profile and (2) the upper 215 cm. With the more shallow profile, the amount of nutrient transported below 75 cm was estimated using the water balance data and subsurface runoff concentrations. With the 215 cm profile, no estimate was made of leaching below 215 cm or lateral flow from the 75-215 cm zone.

Comparing the results using the two different reference soil volumes, the unaccounted-for amounts were almost always less for N and usually less for K when using the 75 cm soil layer with estimated leaching below the 75 cm depth. More unaccounted-for N and K using the 215 cm reference volume indicated that N and K likely leached below 215 cm and/or moved laterally from the plot between the 75 and 215 cm depths; also, N could be denitrified in this lower zone. The amounts of unaccounted-for P were similar with either reference soil volume because very little P was measured in subsurface runoff and very little moved below the 75 cm depth. $Cl^-$ was measured in 1978 only, and soil accumulations were much higher than amounts applied. This indicated that there were errors in the $Cl^-$ data.

Applications of nutrients, crop uptake, subsurface runoff transport and estimated leaching to the B horizon were usually similar for the two growing seasons for each treatment (plot). Crop uptake, losses, and unaccounted-for amounts generally increased as application rates increased. Subsurface runoff transport of N was slightly higher in the dormant season than in either of the two growing seasons for each treatment. For the period

TABLE 57. NUTRIENT MASS BALANCE INCLUDING SUBSURFACE FLOW (PLOT 6)

| Time period | Nutrient | Input, output, and accumulation, kg/ha[+] Applied in effluent | Crop uptake | Subsurface runoff | Soil accumulation[*] 0-75 cm | 0-215 cm | To B horizon | Unaccounted for 75-cm reference[†] | 215-cm reference[‡] |
|---|---|---|---|---|---|---|---|---|---|
| Apr. 1977-<br>Nov. 1977 | N[§] | 289 | 279 | 2 | 27 | 12 | 10 | -29 | -4 |
| | P | 74 | 42 | 0 | 149 | 149 | 1 | -118 | -117 |
| | K | 173 | 241 | 4 | 132 | 230 | 1 | -205 | -302 |
| | Cl⁻ | 172 | 105 | 6 | - | - | 31 | - | - |
| Dec. 1977-<br>Mar. 1978 | N | - | - | 12 | -59 | -88 | 5 | 42[#] | 76[#] |
| | P | - | - | 0 | 24 | 24 | 0 | -24[#] | -24[#] |
| | K | - | - | 5 | 23 | -137 | 3 | -30[#] | 132[#] |
| | Cl⁻ | - | - | 19 | - | - | 3 | - | - |
| Apr. 1978-<br>Oct. 1978 | N | 219 | 168 | 9 | -4 | -2 | 0 | 46 | 44 |
| | P | 50 | 27 | 1 | -83 | -83 | 0 | 105 | 105 |
| | K | 138 | 149 | 2 | -84 | -241 | 0 | 71 | 228 |
| | Cl⁻ | 121 | 50 | 8 | 204 | 497 | 0 | -141 | -434 |
| Apr. 1977-<br>Oct. 1978 | N | 508 | 447 | 23 | -36 | -78 | 15 | 59 | 116 |
| | P | 124 | 69 | 1 | 90 | 90 | 1 | -37 | -36 |
| | K | 311 | 390 | 10 | 71 | -148 | 4 | -164 | 59 |
| | Cl⁻ | 293 | 155 | 33 | - | - | 34 | - | - |

[+] Surface runoff is not shown because it was negligible (less than 2 kg/ha in all cases).

[*] Soil sampling months were April 1977, December 1977, April 1978, and October 1978.

[†] Difference between input and outputs plus accumulation with reference volume equal to upper 75 cm of the soil profile and estimation of mass moving below 75 cm. Negative number means that accounted for more than applied because of large increase in soil levels.

[‡] Unaccounted-for amount using reference volume equal to upper 215 cm of the soil profile with no estimate of mass lost from the 75-215 cm zone. Negative number means that accounted for more than applied because of large increase in soil levels.

[§] N is sum of TKN and $NO_3$-N.

[#] Unaccounted-for amount is difference between soil reduction and outputs. Negative number means that had increase in soil levels or that outputs were greater than reductions in soil levels.

## TABLE 58. NUTRIENT MASS BALANCE INCLUDING SUBSURFACE FLOW (PLOT 5)

| Time period | Nutrient | Input, output, and accumulation, kg/ha[+] | | | | | | Unaccounted for | |
|---|---|---|---|---|---|---|---|---|---|
| | | Applied in effluent | Crop uptake | Subsurface runoff | Soil accumulation[*] | | To B horizon | 75-cm reference[ƒ] | 215-cm reference[≠] |
| | | | | | 0-75 cm | 0-215 cm | | | |
| Apr. 1977-Nov. 1977 | N[§] | 540 | 353 | 21 | -12 | -32 | 111 | 67 | 198 |
| | P | 136 | 42 | 0 | 76 | 76 | 1 | 17 | 18 |
| | K | 327 | 257 | 8 | 104 | 430 | 18 | -60 | -368 |
| | Cl⁻ | 319 | 87 | 20 | - | - | 92 | - | - |
| Dec. 1977-Mar. 1978 | N | - | - | 32 | 1 | -36 | 13 | -46[#] | 4[#] |
| | P | - | - | 0 | 10 | 10 | 0 | -10[#] | -10[#] |
| | K | - | - | 5 | 215 | 358 | 9 | -229[#] | -363[#] |
| | Cl⁻ | - | - | 33 | - | - | 20 | - | - |
| Apr. 1978-Oct. 1978 | N | 560 | 344 | 24 | 34 | -33 | 0 | 158 | 225 |
| | P | 128 | 40 | 1 | -22 | -22 | 0 | 109 | 109 |
| | K | 354 | 279 | 12 | -173 | -364 | 0 | 236 | 427 |
| | Cl⁻ | 305 | 96 | 14 | 118 | 534 | 0 | 77 | -339 |
| Apr. 1977-Oct. 1978 | N | 1,100 | 697 | 77 | 23 | -101 | 124 | 179 | 427 |
| | P | 264 | 82 | 1 | 64 | 64 | 1 | 116 | 117 |
| | K | 681 | 536 | 25 | 146 | 424 | 27 | -53 | -304 |
| | Cl⁻ | 624 | 183 | 66 | - | - | 112 | - | - |

+, *, ƒ, ≠, §, # - See Table 57 for footnotes.

### TABLE 59. NUTRIENT MASS BALANCE INCLUDING SUBSURFACE FLOW (PLOT 4)

| Time period | Nutrient | Input, output, and accumulation, kg/ha[+] |  |  |  |  |  | Unaccounted-for |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Applied in effluent | Crop uptake | Subsurface runoff | Soil accumulation[*] |  | To B horizon | 75-cm reference[†] | 215-cm reference[‡] |
|  |  |  |  |  | 0-75 cm | 0-215 cm |  |  |  |
| Apr. 1977-<br>Nov. 1977 | N[§] | 1,152 | 345 | 50 | -19 | 50 | 204 | 572 | 707 |
|  | P | 281 | 44 | 1 | 709 | 709 | 2 | -475 | -473 |
|  | K | 676 | 279 | 29 | 276 | 230 | 97 | -5 | 138 |
|  | $Cl^-$ | 667 | 75 | 42 | - | - | 149 | - | - |
| Dec. 1977-<br>Mar. 1978 | N | - | - | 60 | -10 | 112 | 22 | -72[#] | -172[#] |
|  | P | - | - | 2 | -454 | -454 | 1 | 451[#] | 452[#] |
|  | K | - | - | 14 | 256 | 144 | 20 | -290[#] | -158[#] |
|  | $Cl^-$ | - | - | 58 | - | - | 28 | - | - |
| Apr. 1978-<br>Oct. 1978 | N | 1,207 | 441 | 44 | 88 | -125 | 96 | 538 | 847 |
|  | P | 274 | 56 | 2 | -39 | -39 | 1 | 254 | 255 |
|  | K | 775 | 332 | 32 | -152 | -199 | 84 | 479 | 610 |
|  | $Cl^-$ | 662 | 106 | 32 | 191 | 172 | 47 | 286 | 352 |
| Apr. 1977-<br>Oct. 1978 | N | 2,359 | 786 | 154 | 59 | 37 | 322 | 1,038 | 1,382 |
|  | P | 555 | 100 | 5 | 216 | 216 | 4 | 230 | 234 |
|  | K | 1,451 | 611 | 75 | 380 | 175 | 201 | 184 | 590 |
|  | $Cl^-$ | 1,329 | 181 | 131 | - | - | 224 | - | - |

+, *, †, ‡, §, # - See Table 57 for footnotes.

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April 1977-October 1978, the subsurface runoff transport was about 4 to 7% of the N applied for the various treatments while crop uptake as percent of applied was 33, 63, and 88% for plots 4, 5, and 6, respectively. Thus, a big difference between treatments was the amount of crop uptake of N, but the large differences between years for each treatment for each nutrient were typically in the levels of nutrients measured in the soil.

During the crop growing season, soil nutrient levels should generally show an increase because of applications in excess of crop uptake. Compared to amounts of N applied, there was relatively little change in soil N during the crop-growing seasons or from April 1977 to October 1978. However, P soil levels increased in 1977 and decreased in 1978 with a net increase for the two years. Compared to applied amounts, there were particularly large accumulations in plots 4 and 6 during 1977. For the 2-year period there was a large percentage of the P unaccounted-for on plots 4 and 6. Part of this unaccounted-for P could be attributed to fixing of P in the soil so that the analytical tests for P did not measure total P in the soil. However, it is difficult to explain the large accumulation in 1977 and the large loss of soil P in the period December 1977 - March 1978 for plot 4. Overall, the soil P levels were variable for these three plots and sampling dates, but the soils data in general shows an increasing level of soil P.

Changes in K soil levels during the growing season were more similar to P changes than to N changes. Again, large changes in K were noted from one sampling to the next and K was generally accumulated in the soil for the 2-year period. However, the amount of unaccounted-for K was often large and this was usually due to variability in soil levels. One probable error which was not identified until 1980 and for which this data has not been corrected was that the procedure used for lagoon sample analysis for K probably resulted in low values for K. Thus, more K was probably applied than was calculated, perhaps 30% to 60% more.

During the crop dormant season, soil levels of N and K would be expected to decrease while P would be expected to remain relatively constant. P increased slightly on plots 5 and 6, and greatly decreased on plot 4 for the period December 1977 - March 1978. Very high P levels were measured in November 1977 on plot 4, and the large decrease in the dormant season tended to offset the large increase in the growing season of 1977. However, P subsurface runoff transport and crop uptake of P were relatively small compared to amounts applied. Thus, the variability of soil P was probably due to experimental error and the inadequacy of the soil P analysis procedure to recover all the soil P.

K soil levels increased during the dormant season except for the 215 cm zone on plot 6. The decrease on plot 6 for December 1977 to March 1978 could be due to lateral transport from the B horizon and leaching below the 215 cm depth. The increases cannot be explained. However, the large decreases from April 1978 to October 1978 indicate that perhaps the March 1978 soil K value was abnormally high.

N losses by subsurface runoff and leaching to the B horizon were greater than the soil reductions in the 75 cm zone for plots 5 and 6 for the period December 1977 - March 1978. Also, there was an increase in N in the 215 cm zone on plot 4. These results indicate that there was perhaps significant mineralization of organic N during the dormant season on plots 4 and 5 which received large amounts of N during the growing season. Otherwise, there should be a decrease due to lateral movement and leaching, and possibly denitrification. The N applied was usually on the order of 10% organic N and would be significant only at high application rates or after several years of application at normal rates.

Overall, variability in soil levels of P, K and $Cl^-$ made it difficult to identify trends in the mass balances for plots 4, 5, and 6 for the period April 1977 - October 1978. Part of the variability for P was probably due to soil adsorption-desorption characteristics and the inadequacy of the analytical procedure to account for all soil P. However, K should not be fixed by this soil and the variability in K accumulation is probably related to unaccounted-for leaching and experimental errors.

Unaccounted-for N was likely lost by soil-water transport from the 75-215 cm zone and by denitrification. Some evidence of denitrification of the $NO_3$-N in the A horizon is that $NO_3$-N/$Cl^-$ ratios in the subsurface flow showed some decreases in winter when the crop was not utilizing N (Figure 27). In addition, $NO_3$-N/$Cl^-$ ratios in soil samples (Figure 28) also decreased from April 1978 to October 1978 while the N applied in excess of crop uptake during the same period exceeded the total $Cl^-$ applied, which in the absence of denitrification would suggest that the $NO_3$-N/$Cl^-$ ratios would have increased. Denitrification was not expected below the A horizon, but $NO_3$-N/$Cl^-$ ratios also decreased from April to October throughout the clay horizon to a depth of 215 cm. However, as noted earlier, $Cl^-$ accumulation in the upper 215 cm of the soil profile on the low and medium rate treatments exceeded $Cl^-$ applied, and thus there was some question as to the accuracy of the $Cl^-$ analysis. Using the 75 cm reference soil volume and assuming that the unaccounted-for N was lost by denitrification, then a large amount of N was volatilized to the air, especially from the high rate plot where 1,038 kg N/ha was unaccounted-for for the period covering two growing seasons.

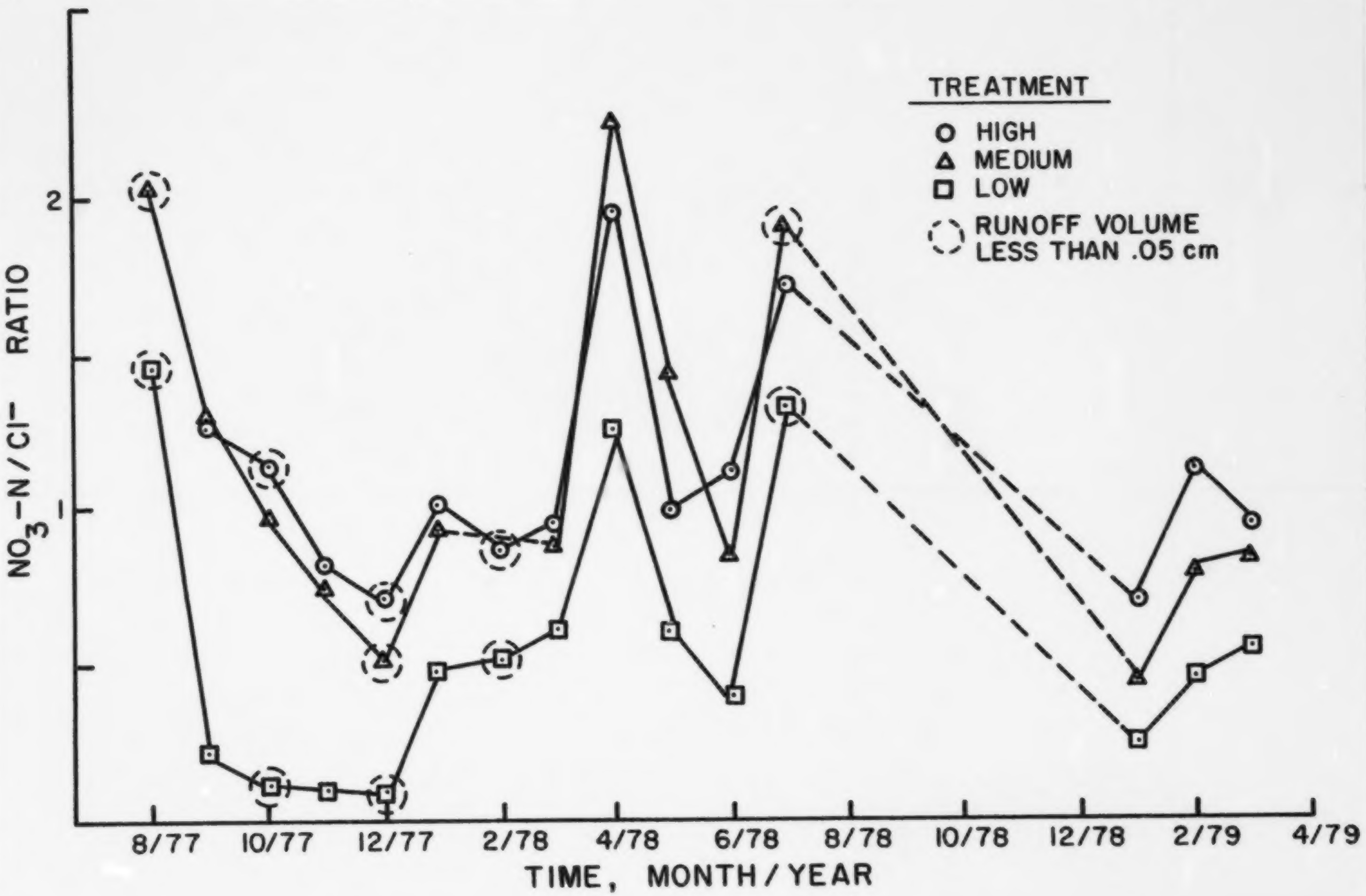

Figure 27. Monthly flow weighted $NO_3$-N/$Cl^-$ ratios in subsurface runoff. (Broken line indicates no runoff).

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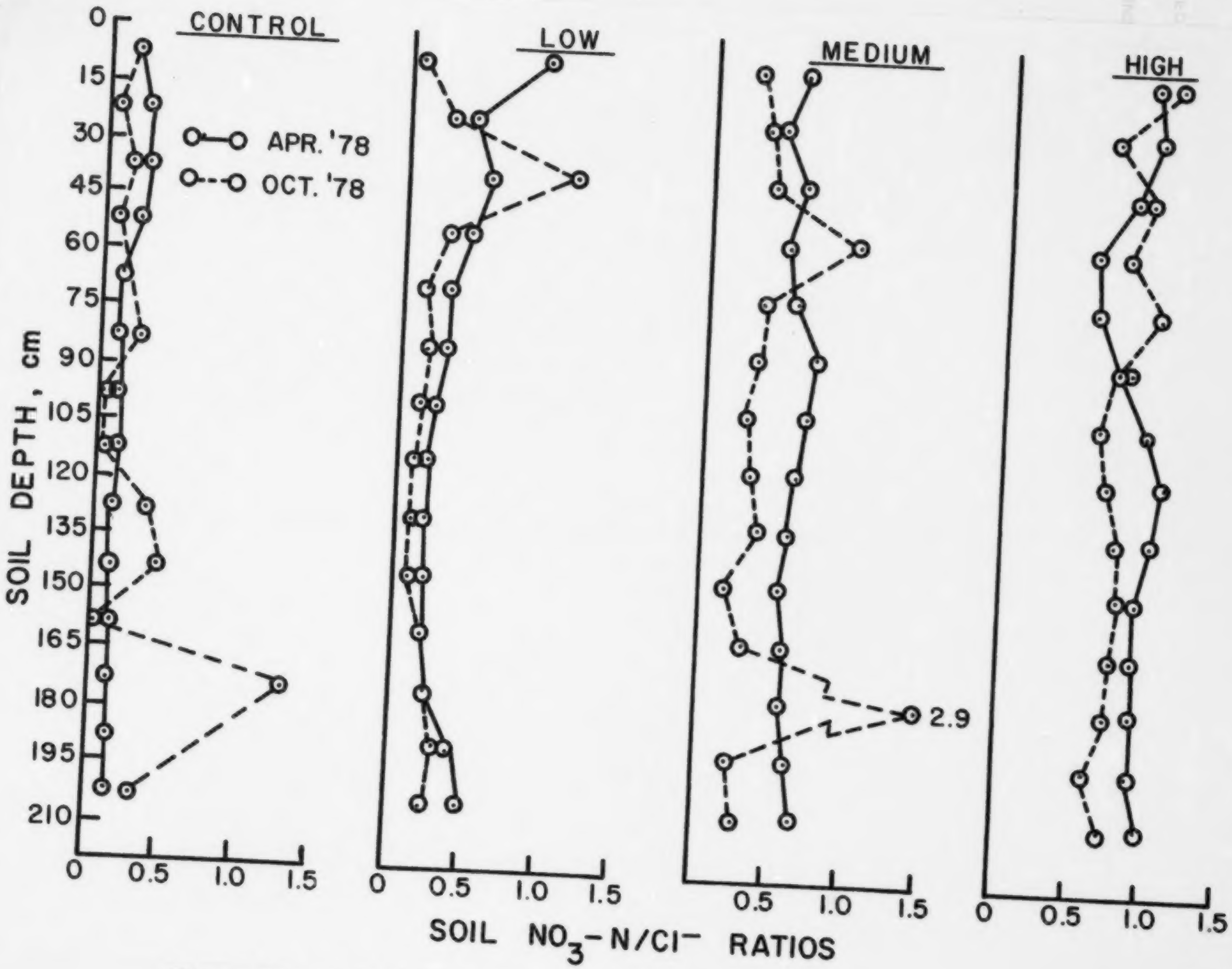

Figure 28. Soil $NO_3$-N/Cl$^-$ ratios as a function or time and depth. (Each value except control is mean of three replications).

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# APPENDIX A

## VARIATION IN IRRIGATION DISTRIBUTION AND LOSSES

An even distribution of effluent on each plot and accurate measurements of amounts of effluent and nutrients applied were desirable in order to reduce experimental error. Variation in effluent distribution and the effects of different sample collection procedures for irrigated effluent were investigated.

Distribution of effluent on the plot was estimated by placing up to 18 cups on the plot. Cups side-by-side varied in volume by less than five percent. However, variation over the plot could be much higher as shown in Table A-1. The one sampling shown in Table A-1 also indicates that the regular irrigation check cups' positions at the center of four equal sections may have overestimated the mean application rate. Clogging of the nozzles and wind were the main factors affecting distribution on the plot. Therefore, larger nozzles and avoiding windy periods for irrigation should improve distribution.

TABLE A-1. VARIATION OF CUP VOLUME ON PLOT[≠]

| Plot No. | No. of cups | Volume, ml<br>Mean | Volume, ml<br>Std. dev. |
|---|---|---|---|
| 3 | 18[*] | 95.9 | 11.2 |
| 5 | 18[*] | 95.3 | 46.8 |
| 9 | 9[+] | 95.7 | 15.6 |
| 9 | 4[δ] | 113.8 | 14.9 |

[≠] Irrigation was during warm day (27°C) with slight wind (5-8 km/hr).

[*] Located two cups at each center of nine equal sections.

[+] Located one cup at each center of nine equal sections.

[δ] Located one cup at each center of four equal sections. This is regular position for four cups used for irrigation check.

Collection cups on the plots were 400 ml plastic beakers and had no means of reducing evaporation of collected effluent until funnels were inserted in the cups in 1978 and 1979 after comparisons of cup volumes with and without funnel inserts were made during part of 1977 (Table A-2). The results indicate that using funnel inserts reduced evaporation from the cups between irrigation and time of measuring volume by 10-13%. However, large variation is evident even for the same irrigation event for the two plots. Also, the irrigation period to irrigate all nine plots was usually about eight hours. The cup volumes were measured normally about 9 AM. Therefore, evaporation should normally have been small with or without funnel inserts and the difference may be partially due to different splash characteristics.

The water meter was reliable during 1978 and 1979 and was compared to cup volumes (Table A-3). The cup volumes often estimated more total volume applied than the water meter did. This could be due to the cups not accurately representing mean application rates because of their location and the pattern of distribution, to errors in volume measurements, and to error in converting from cup volume to ha-cm applied based upon the diameter of the top of the cup. However, the mean ratios of cup volume to water meter volume for 1978 and 1979 were 1.00 and 0.94, respectively. Therefore, on the average, using collection cups with funnel inserts indicated little evaporation of sprinkler irrigated effluent. If, however, the location of the cups resulted in an overestimate of the mean application, as results in Table A-1 implied, then evaporation was still on the order of 10%. Thus, it is possible that the cups without funnel inserts more accurately reflected the amount of liquid reaching the plots than the cups with funnel inserts did. Evaporation of irrigated liquid from the vegetation and soil surface may also be greater than from the cups. Thus, these observations are presented to indicate that it is difficult to determine what the actual water and nutrient inputs to the soil-vegetation system are with sprinkler irrigation.

Losses of nutrients by volatilization, oxidation, or other means were also of concern in determining nutrient inputs to the soil-vegetation system. Losses could occur during irrigation and after irrigation before the samples were collected. Concentrations in the lagoon liquid and in liquid collected in cups on the plot are presented in Table A-4 for one event. Three samples were analyzed for each situation to indicate variation in samples and laboratory analyses. Each of the chemical parameters analyzed had lower average concentrations in the cups than in the lagoon except TOC. However, the variation between analyses of the same sample are sometimes as great as between the lagoon and cup samples. Possible explanations of the reductions could be $NH_3$-N volatilization for TKN and $NH_3$-N, and oxidation of organic matter for COD. However, the TP and O-$PO_4$-P reductions are not expected. Differences in the lagoon liquid sample and what is actually pumped through the lagoon pump intake may exist and be variable for different parameters.

Effect of letting the cup sample set in the field for different time periods after irrigation is also presented in Table A-4. Cups had funnel inserts and little or no effect was seen for one hr and 2 hrs after irrigation. Leaving the sample 24 hrs caused several parameters to

## TABLE A-2. EVAPORATION FROM EFFLUENT COLLECTION CUPS

| | | Effluent amount measured, cm | | | | Evaporation, % | |
|---|---|---|---|---|---|---|---|
| | | Plot 2 | | Plot 4 | | | |
| Date | Time* | Open | Funnel | Open | Funnel | Plot 2 | Plot 4 |
| 1977 | | | | | | | |
| 0418 | D | 0.51 | 0.51 | 1.12 | 1.17 | 0.0 | 4.3 |
| 0427 | D | 1.31 | 1.40 | 0.56 | 0.56 | 6.4 | 0.0 |
| 0603 | D | 0.37 | 0.40 | 1.54 | 1.48 | 7.5 | -4.0 |
| 0611 | D | 0.21 | 0.26 | 1.21 | 1.45 | 19.2 | 16.6 |
| 0618 | N | 0.28 | 0.38 | 2.96 | 3.34 | 26.3 | 11.4 |
| 0709 | N | - | - | 1.94 | 2.08 | - | 6.7 |
| 0716 | N | 1.36 | 1.40 | 4.40 | 4.90 | 2.8 | 10.2 |
| 0719 | N | 0.52 | 0.71 | 1.93 | 2.12 | 26.8 | 9.0 |
| 0722 | N | - | - | 2.07 | 2.49 | - | 16.9 |
| 0727 | N | 0.69 | 0.84 | 3.02 | 3.35 | 17.8 | 9.6 |
| 0729 | N | 0.51 | 0.66 | 2.32 | 2.98 | 22.7 | 22.1 |
| 0812 | N | 0.28 | 0.32 | 0.87 | 0.97 | 12.5 | 10.3 |
| 0819 | N | 0.33 | 0.37 | 0.87 | 1.25 | 10.8 | 30.4 |
| 0826 | N | 0.23 | 0.21 | 0.61 | 0.58 | -9.5 | -5.2 |
| 0902 | N | 0.39 | 0.46 | 0.95 | 1.04 | 10.9 | 8.6 |
| 0916 | N | 0.48 | 0.51 | 0.78 | 0.80 | 5.9 | 2.5 |
| 0923 | N | 0.88 | 0.96 | 1.64 | 1.75 | 8.3 | 6.3 |
| 0930 | N | 0.76 | 0.81 | 1.52 | 1.63 | 6.2 | 6.7 |
| 1007 | N | 0.72 | 1.28 | 1.56 | 2.14 | 43.8 | 27.1 |
| | | | | Mean | | 12.8 | 10.0 |
| | | | | Std. Dev. | | 12.4 | 9.7 |

*Irrigation during night (N) or day (D).

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## TABLE A-3. ESTIMATE OF IRRIGATION EVAPORATION*

| Date | Water meter | Cup collection 1 | Cup/meter ratio | Date | Water meter | Cup collection 1 | Cup/meter ratio |
|---|---|---|---|---|---|---|---|
| 780519 | 9,727 | 11,128 | 1.14 | 790406 | 9,073 | 10,492 | 1.16 |
| 0526 | 10,738 | 11,101 | 1.03 | 0427 | 13,119 | 11,472 | 0.87 |
| | | May Mean | 1.08 | | | April Mean | 1.00 |
| 0602 | 9,360 | 9,470 | 1.01 | 0501 | 12,649 | 13,020 | 1.03 |
| 0609 | 10,220 | - | - | 0504 | 18,308 | 15,598 | 0.85 |
| 0616 | 8,365 | 6,412 | 0.77 | 0511 | 20,984 | 19,319 | 0.92 |
| 0623 | 10,212 | 10,965 | 1.07 | 0518 | 18,664 | 15,711 | 0.84 |
| 0630 | 9,958 | 8,914 | 0.90 | 0525 | 19,425 | 16,949 | 0.87 |
| | | June Mean | 0.94 | | | May Mean | 0.90 |
| 0707 | 9,523 | 10,235 | 1.07 | 0601 | 21,726 | 18,054 | 0.83 |
| 0714 | 11,120 | 9,788 | 0.88 | 0608 | 18,425 | 14,610 | 0.79 |
| 0721 | 11,381 | 14,038 | 1.23 | 0612 | 17,873 | 18,054 | 1.01 |
| 0728 | 11,752 | 12,604 | 1.07 | 0615 | 18,028 | 19,129 | 1.06 |
| | | July Mean | 1.06 | 0619 | 18,671 | 18,274 | 0.98 |
| | | | | 0622 | 18,284 | 17,547 | 0.91 |
| 0804 | 13,819 | 15,912 | 1.15 | 0626 | 17,926 | 18,482 | 1.03 |
| 0811 | 14,353 | 16,608 | 1.16 | 0629 | 17,589 | 18,111 | 1.03 |
| 0818 | 13,062 | 14,247 | 1.09 | | | June Mean | 0.96 |
| 0825 | 12,343 | 14,409 | 1.17 | | | | |
| | | August Mean | 1.14 | 0706 | 17,790 | 18,406 | 1.03 |
| | | | | 0713 | 18,152 | 16,942 | 0.93 |
| 0901 | 13,649 | 12,687 | 0.93 | 0720 | 18,603 | 17,861 | 0.96 |
| 0908 | 11,389 | 10,643 | 0.93 | 0727 | 17,248 | 17,646 | 1.02 |
| 0915 | 11,147 | 8,857 | 0.79 | | | July Mean | 0.98 |
| 0922 | 12,006 | 10,908 | 0.91 | | | | |
| 0929 | 10,367 | 7,021 | 0.68 | 0803 | 18,331 | 16,162 | 0.88 |
| | | September Mean | 0.85 | 0810 | 17,468 | 17,672 | 1.01 |
| | | | | 0817 | 17,203 | 16,805 | 0.98 |
| Mean of all values (1978) | | | 1.00 | 0824 | 13,774 | 12,975 | 0.94 |
| | | | | 0831 | 13,463 | 13,410 | 1.00 |
| | | | | | | August Mean | 0.96 |
| | | | | 0907 | 13,845 | 13,543 | 0.98 |
| | | | | 0914 | 14,398 | 10,140 | 0.70 |
| | | | | 0921 | 13,338 | 12,184 | 0.91 |
| | | | | 0928 | 13,562 | 13,308 | 0.98 |
| | | | | | | September Mean | 0.89 |
| | | | | Mean of all values (1979) | | | 0.94 |

* Estimate of amount of effluent reaching the plots as measured in 4 cups per plot is compared to total effluent pumped (water meter results).

## TABLE A-4. EFFECT OF TIME IN FIELD ON IRRIGATION CUP CONCENTRATIONS[*]

| Sample time | Cup volume, ml | Concentration, mg/l | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | TKN | $NH_3$-N | P | O-$PO_4$-P | COD | TOC | $Cl^-$ |
| From lagoon while irrigating | - | 272 | 272 | 74 | 73 | 446 | 75 | 128 |
| | - | 318 | 300 | 88 | 84 | 426 | 100 | 136 |
| | - | 282 | 273 | 74 | 73 | 446 | 50 | 130 |
| Mean | | 291 | 280 | 77 | 76 | 441 | 75 | 137 |
| Immediately after irrigation | 108 | 279 | 274 | 53 | 43 | 383 | 80 | 134 |
| | 108 | 267 | 259 | 51 | 44 | 407 | 100 | 132 |
| | 80 | 273 | 271 | 47 | 43 | 399 | 100 | 138 |
| Mean | | 273 | 268 | 50 | 43 | 396 | 93 | 135 |
| 1 hour after irrigation | 87 | 267 | 257 | 51 | 44 | | | |
| | 105 | 279 | 278 | 47 | 45 | | | |
| | 88 | 267 | 245 | 43 | 42 | | | |
| Mean | | 271 | 260 | 47 | 44 | | | |
| 2 hours after irrigation | 103 | 264 | 264 | 47 | 41 | | | |
| | 83 | 255 | 252 | 62 | 52 | | | |
| | 96 | 234 | 233 | 54 | 37 | | | |
| Mean | | 251 | 250 | 54 | 43 | | | |
| 24 hours after irrigation (different plot)[≠] | - | 186 | 181 | 49 | 48 | 337 | 50 | 104 |
| | - | 195 | 193 | 41 | 40 | 344 | 15 | 103 |
| | - | 189 | 174 | 44 | 43 | 337 | 40 | 105 |
| Mean | | 190 | 183 | 45 | 44 | 339 | 35 | 104 |

[*] Cups had funnel inserts. Samples were taken August 10 and 11, 1978. Irrigation was during daytime.

[≠] Samples from another plot which was irrigated at same time.

decrease, especially nitrogen. Thus, the timely collection of samples is important and would probably be even more important if open collection cups are used.

The effect on concentration of using funnel inserts in cups is presented in Table A-5. The results are variable, but show on the average that the cups with funnels had higher TKN concentrations and slightly lower COD, $Cl^-$, and P concentrations than the open cups had. Thus, the open cups usually had less liquid and lower nitrogen concentration than the cups with funnels.

In summary, placing collection cups on each plot helped identify variation in areal distribution of irrigated effluent. Utilizing liquid volumes collected in cups located at each center of the four quadrants of the plot may have overestimated the mean application rate. Evaporation from open cups tended to offset this effect, but open cups also allowed ammonia volatilization. Funnel inserts were used in 1978 and 1979 and appeared to reduce evaporation and ammonia volatilization from the cups. Prompt collection of the samples soon after irrigation was also important. Other problems which were observed to affect areal distribution, but were not quantitatively evaluated, were variations in nozzle rotation, nozzle pressure, nozzle clogging, and lagoon concentrations. Overall, the calculated application amounts of effluent and nutrients are probably only within ±10 percent of actual amount applied. Then, there still remains the questions of how much ammonia volatilized from effluent on the vegetation and soil surface, and whether other losses occurred from nutrients which adhered to the vegetation.

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## TABLE A-5. EFFECT OF FUNNEL INSERT ON EFFLUENT CONCENTRATIONS IN COLLECTION CUPS

| Date | Plot 2 | | | Plot 4 | | |
|---|---|---|---|---|---|---|
| | Open mg/l | Funnel mg/l | % Difference* | Open mg/l | Funnel mg/l | % Difference* |
| | | | TKN | | | |
| 1977 | | | | | | |
| 0418 + | 298 | 294 | +1.4 | 303 | 300 | +1.0 |
| 0427 + | 294 | 273 | +7.7 | 286 | 264 | +8.3 |
| 0603 + | 261 | 312 | -16.3 | 273 | 273 | 0.0 |
| 0611 + | 205 | 250 | -18.0 | 303 | 210 | +44.3 |
| 0618 | | | | 237 | 276 | -14.1 |
| 0716 | 366 | 360 | + 1.7 | 335 | 306 | + 9.5 |
| 0719 | 315 | 435 | -27.6 | 444 | 510 | -12.9 |
| 0727 | 328 | 320 | + 2.5 | 342 | 353 | - 3.1 |
| 0729 | 303 | 357 | -15.1 | 339 | 375 | - 9.6 |
| 0812 | 165 | 201 | -17.9 | 222 | 243 | - 8.6 |
| 0819 | 192 | 218 | -11.9 | 258 | 273 | - 5.5 |
| 0826 | 216 | 228 | - 5.3 | 237 | 294 | -19.4 |
| 0902 | 170 | 227 | -25.1 | 267 | 282 | - 5.3 |
| 0916 | 171 | 200 | -14.5 | 166 | 202 | -17.8 |
| 0923 | 207 | 208 | - 0.5 | 207 | 194 | + 6.7 |
| 0930 | 177 | 166 | + 6.6 | 177 | 204 | -13.2 |
| Mean | 244 | 270 | - 8.8 | 275 | 285 | - 2.5 |
| Std Dev. | 68 | 75 | 11.5 | 70 | 79 | 15.4 |
| | | | COD | | | |
| 0418 | 964 | 735 | +31.2 | 806 | 837 | - 3.7 |
| 0427 | 632 | 711 | -11.1 | 679 | 743 | - 8.6 |
| 0603 | 640 | 740 | -15.6 | 565 | 570 | - 0.9 |
| 0611 | 510 | 500 | + 2.0 | 475 | 530 | -10.4 |
| 0618 | 541 | 417 | +29.7 | 494 | 479 | + 3.1 |
| 0716 | 489 | 511 | - 4.3 | 549 | 526 | + 4.4 |
| 0719 | 674 | 582 | +15.8 | 544 | 553 | - 1.6 |
| 0727 | 536 | 552 | - 2.9 | 513 | 521 | - 1.5 |
| 0729 | 561 | 539 | + 4.1 | 508 | 485 | + 4.7 |
| 0812 | 623 | 546 | +14.1 | 515 | 500 | + 3.0 |
| 0819 | 448 | 402 | +10.3 | 448 | 417 | + 7.4 |
| 0826 | | | | 469 | 442 | + 6.1 |
| 0916 | 374 | 378 | - 1.0 | 534 | 527 | + 1.3 |
| 0923 | 324 | 340 | - 4.7 | 355 | 363 | - 2.2 |
| 0930 | 399 | 414 | - 3.6 | 414 | 399 | + 3.8 |
| Mean | 552 | 526 | + 4.6 | 524 | 526 | + 0.3 |
| Std. Dev. | 159 | 132 | 14.1 | 107 | 123 | 5.2 |

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TABLE A-5. (Continued)

| Date | Plot 2 Open | Plot 2 Funnel | Plot 2 % Difference* | Plot 4 Open | Plot 4 Funnel | Plot 4 % Difference* |
|---|---|---|---|---|---|---|
|  | mg/1 |  |  | mg/1 |  |  |
|  |  |  | Cl$^-$ |  |  |  |
| 0418 | 152 | 174 | -10.3 | 170 | 146 | +16.4 |
| 0427 | 140 | 151 | - 7.3 | 153 | 144 | + 6.2 |
| 0603 | 166 | 156 | + 6.4 | 155 | 149 | + 4.0 |
| 0611 | 140 | 146 | - 4.1 | 143 | 143 | 0.0 |
| 0618 | 134 | 120 | +11.7 | 123 | 121 | + 1.6 |
| 0716 | 154 | 152 | + 1.3 | 160 | 158 | + 1.3 |
| 0719 | 165 | 163 | + 1.2 | 162 | 160 | + 1.2 |
| 0727 | 140 | 139 | + 0.7 | 136 | 137 | - 0.7 |
| 0729 | 159 | 153 | + 3.9 | 154 | 154 | 0.0 |
| 0812 | 171 | 163 | + 4.9 | 160 | 157 | + 1.9 |
| 0819 | 136 | 130 | + 4.6 | 147 | 141 | + 4.2 |
| 0826 | 152 | 152 | 0.0 | 144 | 142 | + 1.4 |
| 0902 | 167 | 160 | + 4.4 | 147 | 145 | + 1.4 |
| 0916 | 125 | 122 | + 2.4 | 124 | 125 | - 0.8 |
| 0923 | 118 | 117 | + 0.8 | 119 | 118 | + 0.8 |
| 0930 | 125 | 121 | + 3.3 | 125 | 122 | + 2.4 |
| Mean | 146 | 145 | + 1.5 | 145 | 141 | + 2.6 |
| Std. Dev. | 17 | 18 | 5.3 | 16 | 14 | 4.1 |
|  |  |  | TP |  |  |  |
| 0418 | 60 | 58 | + 3.4 | 58 | 57 | + 1.8 |
| 0603 | 75 | 73 | + 2.7 | 59 | 52 | +13.5 |
| 0611 | 61 | 53 | +15.0 | 56 | 53 | + 5.7 |
| 0618 | 67 | 56 | +19.6 | 61 | 57 | + 7.0 |
| 0716 | 55 | 56 | - 1.8 | 62 | 47 | +31.9 |
| 0719 | 48 | 68 | -29.4 | 89 | 90 | - 1.1 |
| 0727 | 67 | 42 | +59.5 | 71 | 70 | + 1.4 |
| 0729 | 49 | 56 | -12.5 | 53 | 62 | -14.5 |
| 0812 | 58 | 57 | + 1.8 | 47 | 40 | +17.5 |
| 0819 | 34 | 41 | -17.1 | 48 | 64 | -25.0 |
| 0826 | 50 | 41 | +22.0 | 49 | 60 | -18.3 |
| 0902 | 65 | 51 | +27.4 | 56 | 44 | +27.3 |
| 0916 | 43 | 45 | - 4.4 | 48 | 46 | + 4.3 |
| 0923 | 67 | 68 | - 1.5 | 63 | 56 | +12.5 |
| 0930 | 39 | 34 | +14.7 | 37 | 51 | -27.4 |
| Mean | 56 | 53 | + 6.6 | 57 | 57 | + 2.4 |
| Std. Dev. | 12 | 11 | 21.2 | 12 | 12 | 17.6 |

[*] Percent change in concentration of effluent in open cups compared to that in cups with funnel inserts. Four cups per plot were composited for sample analyses.

[+] Irrigation during day instead of night.

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# APPENDIX B

## EXPERIMENTS ON EFFLUENT RESIDUE RETAINED ON FORAGE SURFACES

Weekly applications of lagoon effluent, as applied in this experiment, provided the opportunity for residue accumulation on leaf (and stem) surfaces. Actual accumulations may be minimal because of the washing of leaf surfaces during application or by natural rainfall. However, possible accumulation could adversely influence plant growth and be a factor in subsequent animal response to the forage.

Two experiments were conducted to obtain initial information on washing procedures. These results were used in guidelines for the washing of residue from the surface of forage harvested in 1973 and 1975.

### EXPERIMENT 1

This experiment compares the elemental concentrations washed from fresh plant samples of 10, 20 and 30 g and wash periods of 5, 10 and 15 minutes per 500 ml of solution. The purpose was to determine the appropriate sample weight and wash time to be used in subsequent residue determinations.

The concentrations of N, Mn, Fe and Zn (Table B-1, A) were not significantly altered by sample size or washing time when results were expressed on a total sample base. Of those elements significantly altered by sample size (residue N, K, Ca, Mg, $Cl^-$ and Cu), only Ca and $Cl^-$ concentrations were increased from the 20 to the 30 g sample size. These data show little advantage for using samples larger than 20 g for most elements analyzed. Length of wash significantly influence quantity of the residual N and concentrations of K, $Cl^-$ and Na. The latter three were increased for the wash time of 15 minutes. Generally, little benefit was noted beyond ten minutes of washing for the majority of the elements analyzed.

Washing efficiency was examined by adjusting all concentrations to a 10 g sample size (Table B-1,B). No difference in either sample size or wash time was noted for N present in the residue washed from the forages. Concentrations of all other elements were significantly altered by sample size with a general decline as sample size increased. This indicates that samples of 10 g would probably be adequate for residue determination. However, because of low concentrations of the elements in the washings and the variation associated with small samples, the 20 g sample size was selected for future routine washing.

## TABLE B-1. EFFECT OF SAMPLE SIZE AND WASHING TIME ON AMOUNTS OF ELEMENTS WASHED FROM BERMUDAGRASS IRRIGATED WITH LAGOON EFFLUENT

| | Sample size[†] (g forage) | | | | Wash time[‡] (min.) | | | |
|---|---|---|---|---|---|---|---|---|
| Element | 10 | 20 | 30 | LSD ($P \leq .05$) | 5 | 10 | 15 | LSD ($P \leq .0$ |
| **A. Concentrations based on total sample size at each washing** | | | | | | | | |
| Residue N (mg) | 1.7 | 3.4 | 3.8 | 0.7 | 2.6 | 2.8 | 3.5 | 0.7 |
| N (%) | .017 | .017 | .013 | ns[≠] | .013 | .015 | .018 | ns |
| K (ppm) | 142 | 286 | 290 | 51 | 213 | 224 | 280 | 51 |
| Ca (ppm) | 11 | 16 | 17 | 2.0 | 15 | 14 | 15 | ns |
| Mg (ppm) | 3.1 | 4.1 | 4.1 | .4 | 3.6 | 3.7 | 4.0 | ns |
| Mn (ppm) | .39 | .44 | .42 | ns | .41 | .42 | .43 | ns |
| Cl (ppm) | 54 | 60 | 114 | 14 | 79 | 56 | 93 | 14 |
| Na (ppm) | 14 | 15 | 15 | ns | 14 | 12 | 17 | 2 |
| Fe (ppm) | .23 | .25 | .33 | ns | .25 | .25 | .32 | ns |
| Cu (ppm) | .20 | .25 | .24 | .04 | .23 | .22 | .24 | ns |
| Zn (ppm) | .16 | .25 | .21 | ns | .19 | .23 | .21 | ns |
| **B. Concentration per 10 g of fresh sample** | | | | | | | | |
| Residue N (mg) | 1.7 | 1.7 | 1.3 | ns | 1.3 | 1.5 | 1.8 | ns |
| N (%) | .017 | .008 | .004 | .004 | .008 | .010 | .011 | ns |
| K (ppm) | 142 | 143 | 97 | 29 | 113 | 124 | 145 | ns |
| Ca (ppm) | 11 | 8 | 6 | 1 | 8 | 8 | 8 | ns |
| Mg (ppm) | 3.1 | 2.1 | 1.4 | .30 | 2.1 | 2.1 | 2.3 | ns |
| Mn (ppm) | .39 | .22 | .14 | .09 | .23 | .24 | .27 | ns |
| $Cl^-$ (ppm) | 54 | 30 | 38 | 9 | 42 | 30 | 49 | 9 |
| Na (ppm) | 14 | 7 | 6 | 2 | 9 | 7 | 10 | 2 |
| Fe (ppm) | .23 | .13 | .11 | .04 | .14 | .15 | .17 | ns |
| Cu (ppm) | .20 | .12 | .08 | .02 | .13 | .13 | .14 | ns |
| Zn (ppm) | .16 | .13 | .07 | .05 | .10 | .13 | .12 | ns |

[†] All values are the mean of three replications and three washing times ($n = 9$).

[‡] All values are the mean of three repliations and three sample sizes ($n = 9$).

[≠] ns designates not significant

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Expressing results on a 10 g sample basis showed no effect of washing time on N contained in the wash residue, nor on the concentrations of N, K, Ca, Mg, Mn, Fe, Cu or Zn. Only Na and $Cl^-$ were significantly increased with significances being associated with the unusually low values for the ten min. washing. The lack of response to washing time is of major significance because it suggests that the elements contained in the wash is probably of surface origin and not from internal leaching. Leaching of internal elements would probably result in increased concentrations over time. However, leaching could have occurred during the first five min. wash period. A wash period of ten min. seems appropriate for routine analyses.

EXPERIMENT 2

This study was conducted to compare three methods of washing (hand brushings, standing (soaking-unagitated) and agitation on a platform shaker) the forage, using either water or water plus a detergent. The latter was used to reduce surface tension. The solutions and wash methods were used on two bulk samples. One sample had been irrigated with lagoon effluent and the other had not. The significant main effects and subsequent interactions were many (Table B-2).

TABLE B-2. EFFECTS OF EFFLUENT IRRIGATION, WASH METHOD, AND WASH SOLUTION ON ELEMENT CONCENTRATIONS IN WASHINGS FROM BERMUDAGRASS

| | Main effects | | | Interactions | | | |
|---|---|---|---|---|---|---|---|
| Item | Irrigated vs non (1) | Washing method (2) | Wash solution (3) | 1 X 2 | 1 X 3 | 2 X 3 | 1 X 2X3 |
| A. Plant residue | | | | | | | |
| N (mg) | s[†] | ns | s | ns | ns | ns | ns |
| B. In washing | | | | | | | |
| N (mg) | s | s | s | ns | ns | s | ns |
| K (ppm) | s | ns | ns | s | ns | ns | ns |
| Ca (ppm) | s | s | s | s | s | s | ns |
| Mg (ppm) | s | ns | s | ns | ns | ns | ns |
| Mn (ppm) | ns | s | s | ns | ns | ns | ns |
| Na (ppm) | ns | s | s | ns | ns | s | ns |
| $Cl^-$ (ppm) | s | s | ns | s | ns | ns | ns |
| Fe (ppm) | s | s | s | s | s | s | s |
| Cu (ppm) | s | s | s | s | s | s | s |
| Zn (ppm) | ns | ns | ns | ns | ns | ns | ns |

[†] s = significance at $P \leq 0.01$; ns = not significant.

The significant two-way interactions for N in the wash residue and for K, Ca, Na and $Cl^-$ concentrations were examined and found to be mainly due to departure from parallel lines. Consequently the interactions were ignored and the main effects interpreted. Effluent application increased the quantity of N in the plant residue, and in the washings. Also increased

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were concentrations of K, Ca, Mg, and Na (Table B-3). Wash method altered the quantity of N in the washing as well as concentrations of Ca, Mn, Na and $Cl^-$. N content of the plant residues as well as washing concentrations of N, Ca, Mg, Mn and Na were larger in the wash solution that contained the surfactant. Fe and Cu were more variable, giving a significant three-way interaction. The major discrepancy for both elements appeared to be in the water washing from the bermudagrass exposed to effluent application (Table B-4). In both cases concentrations increased in the shaker method vs brushing which was opposite to the other three data sets.

In general, effluent-treated bermudagrass and water with surfactant resulted in higher concentrations of the elements analyzed. Also, using a brush to physically wash the forage frequently resulted in higher values. This practice is questionable because of the leaf breakage and possibly aiding leaching from the plant tissue. The standing and shaker methods frequently gave similar results. The concentration of elements found from the non-effluent treated forage indicates either leaching from the tissues had occurred or appreciable natural contamination were present on plant surfaces. Washings from non-irrigated forage generally had 33 to 50% of the concentrations found in the washings from lagoon-irrigated forage. These data lead to the adoption of water plus surfactant as a washing media and the platform shaker as a washing method.

## EXPERIMENT 3

Based on the procedures developed during the previous two experiments, the forage from each N treatment (low, medium and high) for a harvest in June, July, August and September was washed to compare element concentrations of the washings. Effluent loading rate significantly altered only two elements (Table B-5). Concentrations of Mg and Cu were significantly altered from the low to the medium N rate. Harvest date significantly influenced all elements except P and $Cl^-$. The major difference occurred between the August and September harvest for most elements. Concentrations of N, Mg, and Na gave a significant N rate X harvest interaction, but these resulted from departure from parallel lines and were ignored.

Apparently, residue accumulating on the tissue surface during the summer did not accumulate differently from varying effluent application rates.

## EXPERIMENT 4

A second year's data on possible residue accumulation on Coastal bermudagrass surfaces from irrigation with effluent was determined in 1975. Harvests in June, July and August were evaluated for each of the three N rates.

In this study, both the harvested, unwashed sample and the washed residue were analyzed for N, P, K, Ca and Mg. Concentrations of these elements (except P) plus Na and $Cl^-$ were determined in the washing. From the analyses (data analyzed as a split plot) N, P, K, Ca and Mg concentrations differed significantly among the unwashed sample, the washed residue

TABLE B-3. MEAN N CONTENT OF PLANT RESIDUES AND CONCENTRATIONS OF ELEMENT IN THE WASHINGS FROM BERMUDAGRASS

| Item | Effluent | | Washing method | | | Wash solution | |
|---|---|---|---|---|---|---|---|
| | with | without | brush | stand | shaker | water | + surfactant |
| A. Plant residue | | | | | | | |
| N (mg) | 719[†] | 297 | 489[‡] | 553 | 481 | 559[§] | 457 |
| LSD[¶] | 56 | | ns | | | 56 | |
| B. In washing | | | | | | | |
| N (mg) | 2.9 | .9 | 2.9 | 1.9 | 1.0 | 1.0 | 2.8 |
| LSD: | 1.0 | | 1.3 | | | 1.0 | |
| K (ppm) | 172 | 46 | 103 | 155 | 69 | 81 | 137 |
| LSD: | 61 | | ns | | | ns | |
| Ca (ppm) | 16 | 6 | 14 | 13 | 6 | 7 | 15 |
| LSD: | 4 | | 5 | | | 4 | |
| Mg (ppm) | 98 | 45 | 77 | 89 | 48 | 46 | 97 |
| LSD: | 49 | | ns | | | 49 | |
| Mn (ppm) | .16 | .16 | .24 | .15 | .09 | .07 | .25 |
| LSD: | ns | | .10 | | | .08 | |
| Na (ppm) | 12 | 11 | 17 | 9 | 8 | 9 | 14 |
| LSD: | ns | | 3 | | | 3 | |
| $Cl^-$ (ppm) | 89 | 25 | 57 | 79 | 35 | 44 | 70 |
| LSD: | 30 | | 36 | | | ns | |
| Zn (ppm) | .56 | .24 | .65 | .38 | .17 | .16 | .64 |
| LSD: | ns | | ns | | | ns | |

---

[†] Values are the mean of three replications, 3 wash methods and two wash solutions ( n = 18).

[‡] Values are the mean of three replications, two effluent treatments and two wash solutions (n = 12)

[§] Values are the mean of three replications, two effluent treatments and three wash methods (n = 18)

[¶] All test for significances made at $P \leq 0.01$

TABLE B-4. IRON AND COPPER CONCENTRATIONS OF WASHINGS FROM BERMUDAGRASS

| Item | Effluent treatment | Water |  |  |  | Water + surfactant |  |  |  | Overall mean |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  | brush | stand | shaker | mean | brush | stand | shaker | mean |  |
| Iron (ppm) | with | .12[†] | .22 | 0.17 | .17 | 1.27 | 1.03 | .35 | .88 | .53 |
|  | without | .20 | .15 | .15 | .17 | .80 | .18 | .18 | .39 | .28 |
|  | Mean | .16 | .18 | .16 | .17 | 1.03 | .60 | .26 | .63 |  |
| Copper (ppm) | with | .15 | .13 | 0.20 | .16 | 1.06 | .31 | .14 | .51 | .33 |
|  | without | .09 | .07 | .05 | .07 | .15 | .12 | .08 | .12 | .10 |
|  | Mean | .12 | .10 | .12 | .11 | 0.61 | .22 | .11 | .31 |  |

LSD ($P < 0.01$)

|  | Fe | Cu |
|---|---|---|
| Effluent treatment (E) | .09 | .10 |
| Method of washing (W) | .11 | .12 |
| Solution (S) | .09 | .10 |
| E X W | .16 | .17 |
| E X S | .13 | .14 |
| W X S | .16 | .18 |
| E X W X S | .22 | .25 |

[†] Each value is the mean of three replications.

## TABLE B-5. EFFECT OF EFFLUENT APPLICATION RATE AND HARVEST DATE ON CONCENTRATIONS OF ELEMENTS IN BERMUDAGRASS WASHINGS

| | Nitrogen rate (effluent application) | | | Harvest date | | | |
|---|---|---|---|---|---|---|---|
| Item | Low | Med | High | June | July | August | September |
| N (mg) | .22[§] | .32 | .34 | .42[‡] | .33 | .30 | .12 |
| LSD[§] | | ns | | | | .11 | |
| P (ppm) | 34 | 29 | 34 | 30 | 33 | 32 | 34 |
| LSD | | ns | | | | ns | |
| K (ppm) | 663 | 751 | 858 | 840 | 870 | 853 | 467 |
| LSD | | ns | | | | 271 | |
| Ca (ppm) | 20 | 25 | 26 | 26 | 26 | 24 | 18 |
| LSD | | ns | | | | 4 | |
| Mg (ppm) | 3.5 | 3.9 | 3.9 | 3.6 | 4.0 | 3.8 | 3.7 |
| LSD | | .2 | | | | .2 | |
| Mn (ppm) | .41 | .50 | .52 | .68 | .54 | .42 | .26 |
| LSD | | ns | | | | .17 | |
| Na (ppm) | 15 | 16 | 17 | 14 | 19 | 16 | 14 |
| LSD | | ns | | | | 3 | |
| Cl⁻ (ppm) | 281 | 236 | 215 | 146 | 295 | 292 | 242 |
| LSD | | ns | | | | ns | |
| Fe (ppm) | .79 | 1.05 | .89 | 1.05 | 1.00 | .78 | .35 |
| LSD | | ns | | | | .68 | |
| Cu (ppm) | .30 | .43 | .48 | .46 | .46 | .43 | .25 |
| LSD | | .14 | | | | .17 | |
| Zn (ppm) | .53 | .32 | .49 | .59 | .59 | .48 | .35 |
| LSD | | ns | | | | .19 | |

[†] Each value is the mean of three replications and four harvest dates (n = 12).

[‡] Each value is the mean of three replications and three application rates (n = 9).

[§] Significance level = $P \leq 0.05$ for nitrogen rates and $P \leq 0.01$ for harvest dates; ns = not significant.

and the washing (Table B-6). Concentrations retained in the washed residue were consistently higher than those in the washing. Summing the concentrations in the washed residue with those in the washing approached concentrations present in the unwashed forage. Respective values for N, K, Ca and Mg were 2.41, 2.33, 0.34 and 0.24%. These accounted for 83 to 95% of the unwashed forage concentrations (Table B-6).

N rates from variable effluent applications altered the concentrations of all elements except $Cl^-$ (Table B-6). Generally, significant increases in concentrations occurred between the low and medium rates. Effluent application did not, in general, significantly increase element concentrations in washing in 1973 (Table B-5); however, concentrations generally increased between the low and medium rates.

Harvest variation was significant also for K, Ca, Mg, Na and $Cl^-$. Concentrations generally decreased from June through August. Most significant changes in concentrations occurred between the June and July harvests. This same trend was also noted in 1973 (Table B-5) and could be partially associated with occurrence and intensity of natural rainfall (Table 4).

Results from Experiment 2 indicated that effluent residue is contained on leaf surfaces (Table B-3, with vs without effluent application); however, the elemental concentrations are in general low. An estimate of the percentage, by concentration, of the elements removed in the wash relative to the unwashed plant concentrations can be determined from the data in Table B-6. N, Ca and Mg concentrations averaged 11, 13 and 13%, respectively. K in the washing averaged 37% of the unwashed plant concentrations. These studies do not provide information on the quantity of elements that may be leached from the tissue during washing. However, such separation is of little consequence from the animal standpoint. Visually, residue accumulations were not a problem nor did they appear to suppress dry matter production. The low concentrations of the elements analyzed in the four washing experiments support these observations.

TABLE B-6. CONCENTRATIONS OF ELEMENTS IN UNWASHED FORAGE, WASHED RESIDUE, AND THE WASHINGS FROM BERMUDAGRASS

| Item | Plant material and washing[†] | | | | Nitrogen rate[‡] (effluent application) | | | | Harvests[§] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Unwashed Forage | Washed residue | Washing | LSD ($P \leq 0.01$) | Low | Med. | High | LSD ($P \leq 0.01$) | June | July | Aug. | LSD ($P \leq 0.01$) |
| | % | | | | | | | | | | | |
| N | 2.58 | 2.12 | 0.29 | 0.18 | 1.47 | 1.68 | 1.84 | 0.18 | 1.54 | 1.75 | 1.70 | ns |
| P | 0.37 | 0.30 | -- | 0.04 | 0.30 | 0.33 | 0.38 | 0.05 | 0.37 | 0.33 | 0.31 | ns |
| K | 2.79 | 1.27 | 1.06 | 0.16 | 1.51 | 1.68 | 1.92 | 0.16 | 1.89 | 1.63 | 1.60 | 0.15 |
| Ca | 0.37 | 0.29 | 0.05 | 0.04 | 0.19 | 0.25 | 0.27 | 0.04 | 0.27 | 0.23 | 0.21 | 0.05 |
| Mg | 0.23 | 0.21 | 0.03 | 0.01 | 0.12 | 0.17 | 0.18 | 0.01 | 0.19 | 0.15 | 0.14 | 0.03 |
| Na | -- | -- | 0.07 | -- | 0.05 | 0.07 | 0.08 | .02 | 0.09 | 0.06 | 0.04 | 0.02 |
| $Cl^-$ | -- | -- | 0.02 | -- | 0.01 | 0.02 | 0.02 | ns | 0.02 | 0.01 | 0.01 | 0.01 |

[†] Each value is the mean of three replications, three loading rates and three harvest dates (n = 27) in 1975.

[‡] Each value is the mean of three replications, three wash fractions, and three harvests (n = 27), except for P which has only two wash fractions (n = 18)

[§] Each value is the mean of three replications, three wash fractions, and three nitrogen rates (n = 27), except for P which has only two wash fractions (n = 18) and Na and Cl which have only one wash fraction (n = 9).

# APPENDIX C

## TABLES SHOWING EFFECT OF SWINE MANURE LAGOON EFFLUENT ON NUTRIENT CONCENTRATIONS IN SOIL

## TABLE C-1. EFFECT OF SWINE MANURE LAGOON EFFLUENT ON SOIL $NO_3$-N

| Sampling Date | Depth | Effluent application rate Low | Effluent application rate Medium | Effluent application rate High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------- | -ppm, dry soil | basis | ----------- | |
| Dec. '73 | 0-15 | .6 | .6 | 1.2 | 0.5 | |
| | 15-30 | .4 | .6 | 1.2 | 0.6 | |
| | 30-45 | .4 | .7 | 1.3 | NS | |
| | 45-60 | .5 | .8 | 1.8 | 0.9 | |
| | 60-75 | 1.0 | 1.5 | 3.3 | 1.0 | |
| Mar. '74 | 0-15 | 0 | .3 | .2 | NS | |
| | 15-30 | 0 | .5 | 1.1 | NS | |
| | 30-45 | 1.1 | 1.3 | 1.3 | NS | |
| | 45-60 | 3.0 | 1.9 | 3.0 | NS | |
| | 60-75 | .9 | 1.8 | 3.8 | 2.0 | |
| June '74 | 0-15 | 0 | 1.5 | 4.8 | NS | |
| | 15-30 | 0 | 0.8 | 8.4 | NS | |
| | 30-45 | .4 | 1.3 | 7.2 | 4.4 | |
| | 45-60 | .9 | 1.1 | 6.8 | NS | |
| | 60-75 | 1.6 | 1.5 | 7.3 | 3.9 | |
| Sept. '74 | 0-15 | .3 | 2.3 | .6 | NS | |
| | 15-30 | .5 | 2.6 | 1.7 | NS | |
| | 30-45 | 1.6 | 4.8 | 6.2 | NS | |
| | 45-60 | 2.4 | 7.6 | 17.4 | NS | |
| | 60-75 | 3.5 | 9.8 | 25.5 | NS | |
| July '75 | 0-15 | 4.7 | 4.8 | 2.9 | NS | 2.0 |
| | 15-30 | 1.2 | 2.1 | 3.3 | NS | 1.0 |
| | 30-45 | .4 | 3.3 | 16.7 | NS | 1.0 |
| | 45-60 | .4 | 9.6 | 30.5 | NS | 1.0 |
| | 60-75 | .3 | 15.9 | 41.6 | 26 | 1.0 |
| | 75-90 | 1.0 | 13.5 | 54.8 | 11 | 1.0 |
| | 90-105 | 2 | 16 | 42 | 16 | 1.0 |
| | 105-120 | 2 | 18 | 47 | 19 | 2.0 |
| | cm | ----------- | -ppm, dry soil | basis | ----------- | |
| Dec. '75 | 0-15 | 4 | 2 | 2 | NS | 2 |
| | 15-30 | 3 | 2 | 3 | NS | 3 |
| | 30-45 | 2 | 3 | 5 | NS | 1 |
| | 45-60 | 1 | 8 | 20 | NS | 1 |
| | 60-75 | 1 | 9 | 34 | NS | 4 |
| | 75-90 | 1 | 11 | 32 | NS | 4 |
| | 90-105 | 2 | 11 | 33 | 7 | 2 |
| | 105-120 | 4 | 11 | 30 | 17 | 3 |
| | 120-135 | 5 | 12 | 27 | 13 | 2 |
| | 135-150 | 6 | 11 | 24 | 9 | 2 |
| | 150-165 | 6 | 10 | 15 | NS | 3 |
| | 165-180 | 7 | 9 | 13 | 3 | 3 |
| | 180-195 | 5 | 7 | 13 | NS | 4 |
| | 195-210 | 5 | 6 | 12 | 4 | 4 |
| | 210-225 | 4 | 7 | 13 | 4 | 4 |
| Apr. '76 | 0-15 | 3 | 6 | 6 | NS | 3 |
| | 15-30 | 3 | 3 | 5 | NS | 2 |
| | 30-45 | 2 | 2 | 6 | NS | 2 |
| | 45-60 | 2 | 2 | 8 | NS | 2 |
| | 60-75 | 2 | 3 | 13 | NS | 2 |
| | 75-90 | 2 | 4 | 17 | NS | 2 |
| | 90-105 | 2 | 7 | 23 | 7 | 2 |
| | 105-120 | 3 | 7 | 26 | 11 | 2 |
| | 120-135 | 4 | 8 | 25 | NS | 2 |
| | 135-150 | 5 | 8 | 22 | NS | 2 |
| | 150-165 | 5 | 8 | 18 | 8 | 2 |
| | 165-180 | 6 | 8 | 15 | 5 | 2 |
| | 180-195 | 5 | 7 | 13 | 3 | 2 |
| | 195-210 | 5 | 6 | 11 | 3 | 2 |

(Continued)

TABLE C-1. (continued)

| Sampling Date | Depth | Effluent application rate |  |  | LSD$_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
|  |  | Low | Medium | High |  |  |
|  | cm | ------------ | ---ppm, dry | soil basis | ---------- |  |
| Nov. '76 | 0-15 | 3 | 2 | 6 | NS | 1 |
|  | 15-30 | 2 | 2 | 6 | NS | 1 |
|  | 30-45 | 4 | 15 | 23 | NS | 1 |
|  | 45-60 | 4 | 18 | 33 | NS | 2 |
|  | 60-75 | 3 | 20 | 36 | 7 | 1 |
|  | 75-90 | 2 | 16 | 35 | 15 | 1 |
|  | 90-105 | 2 | 8 | 27 | 15 | 2 |
|  | 105-120 | 2 | 7 | 24 | 6 | 1 |
|  | 120-135 | 3 | 7 | 20 | 4 | 2 |
|  | 135-150 | 4 | 8 | 21 | 7 | 2 |
|  | 150-165 | 5 | 8 | 21 | 10 | 2 |
|  | 165-180 | 6 | 9 | 19 | NS | 2 |
|  | 180-195 | 5 | 8 | 20 | 11 | 2 |
|  | 195-210 | 5 | 8 | 19 | 11 | 2 |
|  | 210-225 | 5 | 7 | 17 | NS | 2 |
| Apr. '77 | 0-15 | 7 | 4 | 4 | NS | 2 |
|  | 15-30 | 4 | 5 | 3 | NS | 3 |
|  | 30-45 | 4 | 3 | 8 | 4 | 1 |
|  | 45-60 | 4 | 10 | 11 | NS | 1 |
|  | 60-75 | 4 | 12 | 16 | NS | 2 |
|  | 75-90 | 4 | 15 | 21 | NS | 2 |
|  | 90-105 | 4 | 16 | 33 | 9 | 1 |
|  | 105-120 | 3 | 11 | 32 | 12 | 2 |
|  | 120-135 | 3 | 10 | 23 | 6 | 1 |
|  | 135-150 | 5 | 10 | 23 | 10 | 2 |
|  | 150-165 | 5 | 11 | 20 | 11 | 2 |
|  | 165-180 | 5 | 11 | 20 | 10 | 2 |
|  | 180-195 | 5 | 10 | 18 | 9 | 2 |
|  | 195-210 | 5 | 9 | 16 | 7 | 2 |
|  | 210-225 | - | 3 | 26 | - | - |
| Dec. '77 | 0-15 |  | 4 | 4 | NS | 2 |
|  | 15-30 | 3 | 3 | 3 | NS | 2 |
|  | 30-45 | 2 | 3 | 5 | NS | 2 |
|  | 45-60 | 4 | 12 | 13 | NS | 1 |
|  | 60-75 | 3 | 19 | 23 | NS | 1 |
|  | 75-90 | 2 | 14 | 26 | NS | 1 |
|  | 90-105 | 2 | 16 | 37 | 15 | 1 |
|  | 105-120 | 2 | 13 | 43 | 22 | 1 |
|  | 120-135 | 3 | 11 | 34 | 19 | 1 |
|  | 135-150 | 3 | 10 | 30 | 16 | 1 |
|  | 150-165 | 4 | 8 | 26 | 10 | 2 |
|  | 165-180 | 5 | 8 | 22 | 9 | 2 |
|  | 180-195 | 5 | 9 | 22 | 9 | 2 |
|  | 195-210 | 5 | 9 | 22 | 10 | 2 |
| Apr. '78 | 0-15 | 3 | 2 | 2 | NS | 1 |
|  | 15-30 | 1 | 1 | 2 | NS | 1 |
|  | 30-45 | 2 | 2 | 3 | NS | 1 |
|  | 45-60 | 3 | 6 | 8 | NS | 1 |
|  | 60-75 | 3 | 11 | 15 | NS | 1 |
|  | 75-90 | 3 | 12 | 25 | NS | 1 |
|  | 90-105 | 2 | 12 | 36 | 10 | 1 |
|  | 105-120 | 2 | 13 | 38 | 15 | 1 |
|  | 120-135 | 2 | 11 | 32 | 11 | 1 |
|  | 135-150 | 2 | 10 | 29 | 13 | 1 |
|  | 150-165 | 2 | 10 | 25 | 12 | 1 |
|  | 165-180 | 3 | 9 | 21 | 11 | 1 |
|  | 180-195 | 4 | 9 | 20 | 11 | 1 |
|  | 195-210 | 4 | 10 | 22 | 12 | 1 |

(Continued)

TABLE C-1. (continued)

| Sampling Date | Depth | Effluent application rate Low | Effluent application rate Medium | Effluent application rate High | LSD$_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ppm, dry soil basis | | | | |
| Oct. '78 | 0-15 | 2 | 5 | 13 | 6 | 1 |
| | 15-30 | 1 | 6 | 12 | 6 | 2 |
| | 30-45 | 5 | 6 | 14 | NS | 2 |
| | 45-60 | 2 | 6 | 18 | NS | 1 |
| | 60-75 | 4 | 8 | 20 | 9 | 1 |
| | 75-90 | 3 | 7 | 25 | 6 | 2 |
| | 90-105 | 3 | 7 | 24 | 6 | 2 |
| | 105-120 | 3 | 7 | 24 | 7 | 2 |
| | 120-135 | 3 | 10 | 23 | 9 | 2 |
| | 135-150 | 3 | 8 | 22 | 9 | 2 |
| | 150-165 | 4 | 7 | 19 | 6 | 2 |
| | 165-180 | 4 | 8 | 16 | 6 | 2 |
| | 180-195 | 4 | 7 | 16 | 5 | 1 |
| | 195-210 | 4 | 7 | 14 | 4 | 2 |
| | 210-225 | 4 | 7 | 15 | 3 | 2 |
| | 225-240 | 3 | 9 | 15 | 5 | 2 |
| | 240-255 | 4 | 7 | 14 | 4 | 2 |
| | 255-270 | 4 | 7 | 14 | 4 | 1 |
| | 270-285 | 4 | 6 | 12 | 4 | 1 |
| | 285-300 | 4 | 5 | 12 | 5 | 1 |
| | 300-315 | 4 | 5 | 12 | 3 | 2 |
| | 315-330 | 5 | 5 | 11 | NS | 2 |

* The control treatment was not replicated so it cannot be statistically compared with the effluent treatments.

## TABLE C-2. EFFECT OF SWINE MANURE LAGOON EFFLUENT ON DILUTE ACID EXTRACTABLE SOIL P

| Sampling date | Depth | Effluent application rate<br>Low | Medium | High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ppm, dry soil basis | | | | |
| Dec. '73 | 0-8 | 32 | 63 | 84 | NS** | -- |
| | 8-15 | 15 | 27 | 39 | NS | -- |
| | 15-23 | 11 | 12 | 21 | NS | -- |
| | 23-30 | 11 | 9 | 12 | NS | -- |
| | 30-45 | 7 | 7 | 9 | NS | -- |
| | 45-60 | 4 | 4 | 7 | NS | -- |
| | 60-75 | 5 | 3 | 7 | 2.5 | -- |
| Mar. '74 | 0-8 | 33 | 44 | 63 | 8 | -- |
| | 8-15 | 15 | 16 | 23 | 5 | -- |
| | 15-23 | 15 | 12 | 16 | 3 | -- |
| | 23-30 | 10 | 12 | 12 | NS | -- |
| | 30-45 | 6 | 7 | 9 | NS | -- |
| | 45-60 | 2 | 4 | 3 | NS | -- |
| | 60-75 | 2 | 2 | 2 | NS | -- |
| June '74 | 0-8 | 34 | 65 | 90 | 8 | -- |
| | 8-15 | 14 | 19 | 26 | NS | -- |
| | 15-23 | 15 | 10 | 15 | NS | -- |
| | 23-30 | 12 | 9 | 14 | NS | -- |
| | 30-45 | 5 | 6 | 6 | NS | -- |
| | 45-60 | 5 | 5 | 5 | NS | -- |
| | 60-75 | 3 | 4 | 3 | NS | -- |
| Sept. '74 | 0-8 | 62 | 84 | 117 | 31 | -- |
| | 8-15 | 20 | 34 | 66 | 10 | -- |
| | 15-23 | 12 | 16 | 30 | NS | -- |
| | 23-30 | 8 | 11 | 21 | NS | -- |
| | 30-45 | 9 | 12 | 16 | NS | -- |
| | 45-60 | 7 | 5 | 9 | NS | -- |
| | 60-75 | 5 | 4 | 7 | NS | -- |
| July '75 | 0-8 | 77 | 113 | 150 | 28 | 6.0 |
| | 8-15 | 33 | 53 | 88 | 32 | 1.3 |
| | 15-23 | 12 | 17 | 35 | 13 | 1.0 |
| | 23-30 | 8 | 5 | 12 | 5 | .3 |
| | 30-45 | 3 | 3 | 4 | NS | 0 |
| | 45-60 | 1 | 1 | 1 | NS | 0 |
| | 60-75 | 0 | 1 | 1 | NS | 0 |

(Continued)

TABLE C-2. (continued)

| Sampling date | Depth | Effluent application rate Low | Medium | High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ---------ppm, dry soil basis------------ | | | | |
| Nov. '76 | 0-8 | 117 | 162 | 225 | 54 | 74 |
| | 8-15 | 47 | 104 | 184 | 77 | 90 |
| | 15-23 | 23 | 30 | 133 | 75 | 2 |
| | 23-30 | 6 | 29 | 79 | NS | 2 |
| | 30-45 | 1 | 1 | 21 | NS | 1 |
| | 45-60 | 0 | 1 | 3 | 2 | 1 |
| | 60-75 | 1 | 1 | 0 | NS | -- |
| Dec. '77 | 0-8 | 134 | 184 | 273 | 87 | 78 |
| | 8-15 | 79 | 102 | 223 | 107 | 14 |
| | 15-23 | 43 | 88 | 181 | 47 | 2 |
| | 23-30 | 19 | 76 | 124 | NS | 2 |
| | 30-45 | 4 | 9 | 52 | NS | 1 |
| | 45-60 | 3 | 3 | 30 | NS | 1 |
| Oct. '78 | 0-8 | 103 | 147 | 199 | 50 | 96 |
| | 8-15 | 74 | 115 | 157 | NS | 22 |
| | 15-23 | 28 | 60 | 112 | 49 | 4 |
| | 23-30 | 19 | 38 | 88 | 28 | 3 |
| | 30-45 | 13 | 10 | 38 | 27 | 1 |
| | 60-75 | 1 | 2 | 17 | NS | <1 |
| | | 1 | 1 | 0 | NS | 0 |

* The control treatment was not replicated so it cannot be statistically compared with effluent treatments.

**Differences are not significant.

## TABLE C-3. EFFECT OF SWINE MANURE LAGOON EFFLUENT ON DILUTE ACID EXTRACTABLE SOIL K

| Sampling date | Depth | Effluent application rate Low | Medium | High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------ppm, dry soil basis---------- | | | | |
| Dec. '73 | 0-15 | 58 | 77 | 107 | 28 | -- |
| | 15-30 | 18 | 62 | 49 | NS** | -- |
| | 30-45 | 14 | 41 | 39 | NS | -- |
| | 45-60 | 14 | 30 | 38 | NS | -- |
| | 60-75 | 26 | 40 | 51 | NS | -- |
| Mar. '74 | 0-15 | 51 | 54 | 63 | NS | -- |
| | 15-30 | 29 | 38 | 49 | NS | -- |
| | 30-45 | 20 | 25 | 36 | NS | -- |
| | 45-60 | 15 | 22 | 25 | NS | -- |
| | 60-75 | 16 | 21 | 26 | NS | -- |
| June '74 | 0-15 | 63 | 72 | 93 | NS | -- |
| | 15-30 | 19 | 34 | 54 | 13 | -- |
| | 30-45 | 14 | 24 | 39 | 14 | -- |
| | 45-60 | 13 | 23 | 37 | 14 | -- |
| | 60-75 | 12 | 20 | 33 | 9 | -- |
| Sept. '74 | 0-15 | 60 | 53 | 70 | 12 | -- |
| | 15-30 | 35 | 42 | 53 | NS | -- |
| | 30-45 | 28 | 36 | 56 | NS | -- |
| | 45-60 | 20 | 32 | 59 | 30 | -- |
| | 60-75 | 21 | 32 | 55 | 24 | -- |
| July '75 | 0-15 | 55 | 58 | 55 | NS | 30 |
| | 15-30 | 39 | 45 | 46 | NS | 16 |
| | 30-45 | 28 | 50 | 64 | NS | 16 |
| | 45-60 | 20 | 56 | 72 | NS | 16 |
| | 60-75 | 22 | 50 | 63 | NS | 10 |
| | 75-90 | 26 | 37 | 42 | NS | 17 |
| | 90-105 | 22 | 32 | 38 | NS | 14 |
| Dec. '75 | 0-15 | 58 | 54 | 57 | NS | 27 |
| | 15-30 | 34 | 53 | 64 | NS | 9 |
| | 30-45 | 24 | 53 | 75 | NS | 9 |
| | 45-60 | 20 | 37 | 102 | NS | 9 |
| | 60-75 | 25 | 42 | 92 | 46 | 7 |
| | 75-90 | 22 | 29 | 67 | 32 | 10 |
| | 90-105 | 16 | 18 | 55 | NS | 7 |
| | 105-120 | 14 | 18 | 38 | NS | 7 |
| | 120-135 | 13 | 14 | 26 | 11 | 8 |
| | 135-150 | 11 | 10 | 18 | 5 | 5 |
| | 150-165 | 11 | 11 | 14 | NS | 7 |
| | 165-180 | 10 | 11 | 12 | NS | 8 |
| | 180-195 | 11 | 11 | 13 | NS | 6 |
| | 195-210 | 17 | 10 | 11 | NS | 6 |
| | 210-225 | 14 | 9 | 14 | NS | 5 |
| Apr. '76 | 0-15 | 55 | 62 | 44 | NS | -- |
| | 15-30 | 43 | 47 | 48 | 3 | 23 |
| | 30-45 | 27 | 42 | 65 | NS | 13 |
| | 45-60 | 18 | 33 | 74 | NS | 14 |
| | 60-75 | 20 | 40 | 84 | 40 | 13 |
| | 75-90 | 22 | 30 | 69 | 33 | 9 |
| | 90-105 | 19 | 19 | 62 | NS | 11 |
| | 105-120 | 15 | 14 | 50 | NS | 11 |
| | 120-135 | 11 | 11 | 30 | NS | 10 |
| | 135-150 | 10 | 10 | 17 | NS | 10 |
| | 150-165 | 9 | 10 | 12 | NS | 9 |
| | 165-180 | 8 | 9 | 9 | NS | 8 |
| | 180-195 | 8 | 9 | 8 | NS | 10 |
| | 195-210 | 8 | 8 | 12 | NS | 10 |

(Continued)

TABLE C-3. (continued)

| Sampling date | Depth | Effluent application rate |  |  | LSD$_{0.05}$ | Control* | Sampling date | Depth | Effluent application rate |  |  | LSD$_{0.05}$ | Control* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | Low | Medium | High |  |  |  |  | Low | Medium | High |  |  |
|  | cm | ----------ppm, dry soil basis---------- |  |  |  |  |  | cm | ----------ppm, dry soil basis---------- |  |  |  |  |
| Nov. '76 | 0-15 | 82 | 59 | 69 | 11 | 31 | Dec. '77 | 0-15 | 70[†] | 59 | 75 | NS | 50 |
|  | 15-30 | 48 | 63 | 75 | NS | 9 |  | 15-30 | 57 | 54 | 62 | NS | 16 |
|  | 30-45 | 23 | 82 | 101 | NS | 13 |  | 30-45 | 42 | 54 | 97 | NS | 20 |
|  | 45-60 | 17 | 57 | 93 | NS | 12 |  | 45-60 | 32 | 72 | 107 | NS | 24 |
|  | 60-75 | 27 | 57 | 93 | 29 | 8 |  | 60-75 | 26 | 53 | 116 | NS | 13 |
|  | 75-90 | 23 | 34 | 85 | 33 | 8 |  | 75-90 | 23 | 57 | 118 | NS | 10 |
|  | 90-105 | 18 | 19 | 75 | 46 | 8 |  | 90-105 | 16 | 40 | 104 | 50 | 14 |
|  | 105-120 | 15 | 15 | 57 | NS | 9 |  | 105-120 | 14 | 25 | 93 | 53 | 14 |
|  | 120-135 | 12 | 12 | 34 | NS | 10 |  | 120-135 | 11 | 16 | 60 | NS | 9 |
|  | 135-150 | 11 | 10 | 26 | NS | 9 |  | 135-150 | 8 | 14 | 43 | NS | 9 |
|  | 150-165 | 10 | 10 | 19 | NS | 8 |  | 150-165 | 9 | 12 | 31 | NS | 7 |
|  | 165-180 | 9 | 9 | 18 | NS | 7 |  | 165-180 | 9 | 9 | 22 | NS | 6 |
|  | 180-195 | 9 | 9 | 15 | NS | 7 |  | 180-195 | 11 | 7 | 23 | NS | 6 |
|  | 195-210 | 10 | 8 | 16 | NS | 6 |  | 195-210 | 8 | 7 | 19 | 15 | 6 |
|  | 210-225 | 8 | 9 | 13 | 3 | 7 |  |  |  |  |  |  |  |
| Apr. '77 | 0-15 | 54 | 52 | 40 | NS | 28 | Apr. '78 | 0-15 | 54 | 53 | 58 | NS | 42 |
|  | 15-30 | 53 | 46 | 44 | NS | 14 |  | 15-30 | 56 | 56 | 61 | NS | 13 |
|  | 30-45 | 29 | 64 | 74 | NS | 22 |  | 30-45 | 57 | 90 | 93 | NS | 17 |
|  | 45-60 | 22 | 60 | 74 | NS | 17 |  | 45-60 | 40 | 94 | 135 | NS | 13 |
|  | 60-75 | 25 | 51 | 72 | NS | 5 |  | 60-75 | 44 | 85 | 139 | 58 | 9 |
|  | 75-90 | 26 | 49 | 86 | 22 | 5 |  | 75-90 | 30 | 67 | 133 | 22 | 11 |
|  | 90-105 | 43 | 23 | 81 | NS | 6 |  | 90-105 | 22 | 56 | 117 | 30 | 10 |
|  | 105-120 | 17 | 15 | 62 | NS | 6 |  | 105-120 | 16 | 39 | 88 | 31 | 21 |
|  | 120-135 | 15 | 14 | 58 | NS | 6 |  | 120-135 | 14 | 28 | 66 | 31 | 8 |
|  | 135-150 | 11 | 11 | 37 | NS | 6 |  | 135-150 | 17 | 20 | 47 | NS | 8 |
|  | 150-165 | 8 | 10 | 22 | NS | 6 |  | 150-165 | 12 | 17 | 39 | NS | 7 |
|  | 165-180 | 7 | 10 | 17 | NS | 4 |  | 165-180 | 11 | 13 | 37 | NS | 7 |
|  | 180-195 | 8 | 7 | 17 | NS | 4 |  | 180-195 | 10 | 14 | 31 | NS | 7 |
|  | 195-210 | 6 | 6 | 13 | NS | 4 |  | 195-210 | 10 | 12 | 33 | 18 | 7 |
|  | 210-225 | -- | 4 | 24 | -- | 4 |  |  |  |  |  |  |  |

(continued)

[†] Plot 7 rerun. Ratio of rerun/original at each depth used to change data.

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TABLE C-3. (continued)

| Sampling date | Depth | Effluent application rate Low | Effluent application rate Medium | Effluent application rate High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------ppm, dry soil basis---------- | | | | |
| Oct. '78 | 0-15 | 76 | 80 | 94 | NS | 42 |
| | 15-30 | 43 | 53 | 69 | 14 | 10 |
| | 30-45 | 53 | 61 | 76 | NS | 29 |
| | 45-60 | 40 | 48 | 95 | NS | 17 |
| | 60-75 | 30 | 85 | 112 | 59 | 6 |
| | 75-90 | 26 | 63 | 130 | 38 | 7 |
| | 90-105 | 17 | 43 | 116 | 40 | 8 |
| | 105-120 | 12 | 30 | 90 | 39 | 8 |
| | 120-135 | 11 | 16 | 44 | 23 | 6 |
| | 135-150 | 9 | 20 | 32 | NS | 6 |
| | 150-165 | 8 | 11 | 27 | 14 | 6 |
| | 165-180 | 7 | 9 | 20 | 11 | 5 |
| | 180-195 | 8 | 9 | 15 | 5 | 5 |
| | 195-210 | 10 | 8 | 12 | NS | 6 |
| | 210-225 | 8 | 8 | 12 | NS | 3 |
| | 225-240 | 8 | 9 | 12 | NS | 3 |
| | 240-255 | 6 | 9 | 13 | NS | 3 |
| | 255-270 | 6 | 6 | 16 | NS | 4 |
| | 270-285 | 6 | 6 | 16 | NS | 3 |
| | 285-300 | 6 | 8 | 17 | NS | 4 |
| | 300-315 | 5 | 6 | 17 | NS | 4 |
| | 315-330 | 4 | 6 | 12 | NS | 4 |

*The control treatment was not replicated so it cannot be statistically compared with the effluent treatments.

**Differences are not significant.

## TABLE C-4. EFFECT OF SWINE MANURE LAGOON EFFLUENT ON DILUTE ACID EXTRACTABLE SOIL Ca

| Sampling date | Depth | Effluent application rate Low | Effluent application rate Medium | Effluent application rate High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------ppm, dry soil basis---------- | | | | |
| Dec. '73 | 0-15 | 140 | 116 | 124 | NS** | -- |
| | 15-30 | 49 | 56 | 38 | NS | -- |
| | 30-45 | 47 | 48 | 47 | NS | -- |
| | 45-60 | 33 | 39 | 40 | NS | -- |
| | 60-75 | 30 | 53 | 44 | NS | -- |
| Mar. '74 | 0-15 | 94 | 112 | 107 | NS | -- |
| | 15-30 | 64 | 64 | 54 | NS | -- |
| | 30-45 | 45 | 49 | 54 | NS | -- |
| | 45-60 | 35 | 51 | 47 | NS | -- |
| | 60-75 | 40 | 63 | 44 | NS | -- |
| June '74 | 0-15 | 120 | 100 | 120 | NS | -- |
| | 15-30 | 54 | 42 | 64 | 16 | -- |
| | 30-45 | 50 | 37 | 37 | NS | -- |
| | 45-60 | 52 | 52 | 39 | NS | -- |
| | 60-75 | 42 | 53 | 41 | NS | -- |
| Sept. '74 | 0-15 | 113 | 101 | 114 | NS | -- |
| | 15-30 | 47 | 47 | 70 | NS | -- |
| | 30-45 | 50 | 47 | 56 | NS | -- |
| | 45-60 | 45 | 37 | 50 | NS | -- |
| | 60-75 | 48 | 51 | 59 | NS | -- |
| July '75 | 0-15 | 151 | 189 | 142 | NS | 122 |
| | 15-30 | 52 | 61 | 49 | NS | 61 |
| | 30-45 | 25 | 33 | 37 | NS | 86 |
| | 45-60 | 22 | 77 | 50 | NS | 70 |
| | 60-75 | 25 | 61 | 63 | NS | 44 |
| | 75-90 | 44 | 101 | 80 | NS | 44 |
| | 90-105 | 46 | 228 | 53 | NS | 38 |
| | 105-120 | 27 | 45 | 49 | NS | 30 |
| Dec. '75 | 0-15 | 214 | 174 | 163 | NS | 303 |
| | 15-30 | 67 | 76 | 69 | NS | 42 |
| | 30-45 | 41 | 69 | 41 | NS | 44 |
| | 45-60 | 35 | 44 | 69 | NS | 88 |
| | 60-75 | 44 | 38 | 67 | NS | 48 |
| | 75-90 | 49 | 55 | 71 | NS | 34 |
| | 90-105 | 38 | 53 | 56 | NS | 29 |
| | 105-120 | 33 | 33 | 54 | NS | 34 |
| | 120-135 | 22 | 48 | 56 | NS | 29 |
| | 135-150 | 22 | 21 | 37 | NS | 17 |
| | 150-165 | 20 | 22 | 25 | NS | 15 |
| | 165-180 | 23 | 24 | 24 | NS | 19 |
| | 180-195 | 27 | 17 | 26 | NS | 12 |
| | 195-210 | 22 | 17 | 16 | NS | 14 |
| | 210-225 | 38 | 15 | 18 | NS | 13 |
| Apr. '76 | 0-15 | 205 | 180 | 151 | NS | 198 |
| | 15-30 | 84 | 68 | 83 | NS | 38 |
| | 30-45 | 46 | 47 | 47 | NS | 76 |
| | 45-60 | 44 | 43 | 46 | NS | 69 |
| | 60-75 | 51 | 31 | 61 | NS | 43 |
| | 75-90 | 56 | 51 | 67 | NS | 37 |
| | 90-105 | 50 | 61 | 65 | NS | 31 |
| | 105-120 | 45 | 47 | 68 | 18 | 27 |
| | 120-135 | 37 | 40 | 60 | NS | 36 |
| | 135-150 | 29 | 37 | 47 | 11 | 23 |
| | 150-165 | 25 | 28 | 32 | NS | 19 |
| | 165-180 | 24 | 25 | 19 | NS | 20 |
| | 180-195 | 25 | 24 | 34 | NS | 16 |
| | 195-210 | 23 | 21 | 26 | NS | 19 |

(Continued)

TABLE C-4. (continued)

| Sampling date | Depth | Effluent application rate Low | Effluent application rate Medium | Effluent application rate High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------ppm, dry soil basis---------- | | | | |
| Nov. '76 | 0-15 | 193 | 163 | 191 | NS | 297 |
| | 15-30 | 52 | 88 | 99 | 21 | 60 |
| | 30-45 | 38 | 46 | 49 | NS | 63 |
| | 45-60 | 44 | 55 | 56 | NS | 58 |
| | 60-75 | 54 | 66 | 65 | NS | 52 |
| | 75-90 | 59 | 63 | 69 | NS | 45 |
| | 90-105 | 57 | 66 | 66 | NS | 39 |
| | 105-120 | 42 | 48 | 66 | 15 | 22 |
| | 120-135 | 61 | 41 | 59 | NS | 20 |
| | 135-150 | 35 | 34 | 55 | 13 | 20 |
| | 150-165 | 36 | 31 | 52 | NS | 22 |
| | 165-180 | 54 | 30 | 43 | NS | 41 |
| | 180-195 | 30 | 24 | 41 | NS | 19 |
| | 195-210 | 31 | 22 | 36 | NS | 18 |
| | 210-225 | 29 | 21 | 35 | NS | 20 |
| Apr. '77 | 0-15 | 268 | 190 | 163 | 60 | 239 |
| | 15-30 | 85 | 82 | 98 | NS | 36 |
| | 30-45 | 54 | 43 | 76 | NS | 58 |
| | 45-60 | 42 | 49 | 46 | NS | 116 |
| | 60-75 | 36 | 50 | 59 | NS | 54 |
| | 75-90 | 51 | 66 | 68 | NS | 39 |
| | 90-105 | 61 | 64 | 80 | NS | 27 |
| | 105-120 | 51 | 72 | 72 | NS | 23 |
| | 120-135 | 50 | 56 | 64 | NS | 28 |
| | 135-150 | 35 | 44 | 64 | 19 | 27 |
| | 150-165 | 29 | 47 | 44 | NS | 23 |
| | 165-180 | 29 | 30 | 107 | NS | 21 |
| | 180-195 | 27 | 30 | 40 | NS | 20 |
| | 195-210 | 24 | 25 | 30 | NS | 28 |
| | 210-225 | -- | 17 | 32 | -- | 21 |
| Dec. '77 | 0-15 | 207 | 123 | 127 | 71 | 256 |
| | 15-30 | 69 | 107 | 46 | NS | 23 |
| | 30-45 | 32 | 42 | 54 | NS | 23 |
| | 45-60 | 33 | 51 | 57 | NS | 72 |
| | 60-75 | 25 | 56 | 74 | NS | 95 |
| | 75-90 | 41 | 42 | 73 | NS | 43 |
| | 90-105 | 43 | 68 | 71 | NS | 29 |
| | 105-120 | 38 | 64 | 90 | NS | 25 |
| | 120-135 | 23 | 47 | 66 | 25 | 8 |
| | 135-150 | 19 | 33 | 52 | 22 | 21 |
| | 150-165 | 23 | 30 | 43 | NS | 8 |
| | 165-180 | 24 | 19 | 36 | NS | 15 |
| | 180-195 | 25 | 18 | 37 | NS | 17 |
| | 195-210 | 20 | 21 | 44 | NS | 20 |
| Apr. '78 | 0-15 | 116 | 85 | 100 | NS | 103 |
| | 15-30 | 73 | 71 | 53 | NS | 28 |
| | 30-45 | 47 | 59 | 55 | NS | 42 |
| | 45-60 | 39 | 58 | 63 | NS | 74 |
| | 60-75 | 40 | 50 | 58 | NS | 51 |
| | 75-90 | 47 | 48 | 61 | NS | 34 |
| | 90-105 | 48 | 44 | 66 | NS | 24 |
| | 105-120 | 45 | 51 | 61 | NS | 26 |
| | 120-135 | 39 | 53 | 56 | NS | 15 |
| | 135-150 | 38 | 44 | 52 | NS | 16 |
| | 150-165 | 28 | 40 | 46 | NS | 14 |
| | 165-180 | 27 | 34 | 40 | NS | 13 |
| | 180-195 | 28 | 33 | 40 | 9 | 13 |
| | 195-210 | 29 | 31 | 43 | 7 | 12 |

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TABLE C-4. (continued)

| Sampling date | Depth | Effluent application rate Low | Effluent application rate Medium | Effluent application rate High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------ppm, dry soil basis---------- | | | | |
| Oct. '78 | 0-15 | 209 | 114 | 68 | 41 | 389 |
| | 15-30 | 68 | 99 | 45 | 37 | 43 |
| | 30-45 | 41 | 45 | 48 | NS | 84 |
| | 45-60 | 35 | 39 | 57 | NS | 106 |
| | 60-75 | 48 | 55 | 80 | NS | 52 |
| | 75-90 | 49 | 62 | 83 | NS | 34 |
| | 90-105 | 54 | 64 | 88 | NS | 37 |
| | 105-120 | 52 | 62 | 84 | NS | 32 |
| | 120-135 | 34 | 49 | 65 | 23 | 28 |
| | 135-150 | 33 | 49 | 58 | NS | 26 |
| | 150-165 | 30 | 35 | 54 | 13 | 24 |
| | 165-180 | 29 | 27 | 44 | NS | 20 |
| | 180-195 | 29 | 28 | 41 | 10 | 24 |
| | 195-210 | 22 | 28 | 34 | NS | 26 |
| | 210-225 | 33 | 33 | 34 | NS | 23 |
| | 225-240 | 33 | 35 | 33 | NS | 18 |
| | 240-255 | 27 | 31 | 34 | 5 | 15 |
| | 255-270 | 27 | 26 | 36 | NS | 17 |
| | 270-285 | 26 | 27 | 36 | NS | 16 |
| | 285-300 | 26 | 22 | 37 | NS | 16 |
| | 300-315 | 26 | 25 | 35 | NS | 18 |
| | 315-330 | 28 | 29 | 31 | NS | 18 |

* The control treatment was not replicated so it cannot be statistically compared with the effluent treatments.

** Differences are not significant

## TABLE C-5. EFFECT OF SWINE MANURE LAGOON EFFLUENT ON DILUTE ACID EXTRACTABLE SOIL Mg

| Sampling date | Depth | Effluent application rate Low | Effluent application rate Medium | Effluent application rate High | LSD$_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------ppm, dry soil basis---------- | | | | |
| Dec. '73 | 0-15 | 26 | 24 | 25 | NS** | -- |
| | 15-30 | 9 | 13 | 10 | NS | -- |
| | 30-45 | 8 | 10 | 9 | NS | -- |
| | 45-60 | 7 | 8 | 9 | NS | -- |
| | 60-75 | 6 | 9 | 10 | NS | -- |
| Mar. '74 | 0-15 | 20 | 25 | 23 | 3 | -- |
| | 15-30 | 12 | 16 | 13 | NS | -- |
| | 30-45 | 9 | 11 | 10 | NS | -- |
| | 45-60 | 9 | 12 | 10 | NS | -- |
| | 60-75 | 9 | 12 | 11 | NS | -- |
| June '74 | 0-15 | 21 | 22 | 24 | NS | -- |
| | 15-30 | 9 | 13 | 20 | 3 | -- |
| | 30-45 | 8 | 11 | 14 | 4 | -- |
| | 45-60 | 10 | 12 | 14 | NS | -- |
| | 60-75 | 10 | 11 | 13 | NS | -- |
| Sept. '74 | 0-15 | 24 | 22 | 22 | NS | -- |
| | 15-30 | 14 | 17 | 18 | NS | -- |
| | 30-45 | 13 | 16 | 18 | 3 | -- |
| | 45-60 | 11 | 13 | 17 | NS | -- |
| | 60-75 | 12 | 15 | 18 | NS | -- |
| July '75 | 0-15 | 44 | 34 | 36 | 4 | 29 |
| | 15-30 | 16 | 14 | 13 | NS | 9 |
| | 30-45 | 8 | 16 | 19 | NS | 14 |
| | 45-60 | 8 | 26 | 26 | NS | 20 |
| | 60-75 | 8 | 25 | 32 | 17 | 22 |
| | 75-90 | 11 | 21 | 37 | 4 | 20 |
| | 90-105 | 13 | 22 | 29 | 10 | 20 |
| | 105-120 | 13 | 12 | 23 | 8 | 16 |
| Dec. '75 | 0-15 | 66 | 39 | 37 | 14 | 36 |
| | 15-30 | 22 | 23 | 21 | NS | 9 |
| | 30-45 | 11 | 32 | 17 | NS | 7 |
| | 45-60 | 14 | 23 | 31 | NS | 11 |
| | 60-75 | 14 | 22 | 35 | NS | 14 |
| | 75-90 | 14 | 19 | 29 | NS | 12 |
| | 90-105 | 14 | 16 | 29 | 10 | 11 |
| | 105-120 | 14 | 15 | 26 | 10 | 12 |
| | 120-135 | 13 | 15 | 21 | NS | 12 |
| | 135-150 | 14 | 15 | 20 | NS | 9 |
| | 150-165 | 13 | 14 | 15 | NS | 10 |
| | 165-180 | 11 | 12 | 14 | NS | 10 |
| | 180-195 | 11 | 11 | 12 | NS | 9 |
| | 195-210 | 11 | 11 | 10 | NS | 10 |
| | 210-225 | 13 | 10 | 11 | NS | 10 |
| Apr. '76 | 0-15 | 66 | 46 | 30 | 11 | 20 |
| | 15-30 | 29 | 27 | 25 | NS | 8 |
| | 30-45 | 14 | 25 | 20 | NS | 8 |
| | 45-60 | 14 | 22 | 25 | 7 | 10 |
| | 60-75 | 26 | 18 | 41 | NS | 13 |
| | 75-90 | 16 | 21 | 30 | NS | 12 |
| | 90-105 | 15 | 17 | 29 | 8 | 11 |
| | 105-120 | 14 | 16 | 30 | 6 | 10 |
| | 120-135 | 13 | 18 | 24 | 6 | 12 |
| | 135-150 | 13 | 19 | 21 | 4 | 10 |
| | 150-165 | 12 | 18 | 21 | 4 | 10 |
| | 165-180 | 12 | 15 | 15 | 3 | 12 |
| | 180-195 | 12 | 14 | 13 | NS | 11 |
| | 195-210 | 11 | 11 | 13 | NS | 12 |

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TABLE C-5 (continued)

| Sampling date | Depth | Effluent application rate Low | Effluent application rate Medium | Effluent application rate High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------ppm, dry soil basis---------- | | | | |
| Nov. '76 | 0-15 | 53 | 35 | 38 | NS | 32 |
| | 15-30 | 23 | 23 | 21 | NS | 10 |
| | 30-45 | 15 | 28 | 25 | NS | 8 |
| | 45-60 | 17 | 28 | 27 | 5 | 12 |
| | 60-75 | 14 | 33 | 32 | 13 | 16 |
| | 75-90 | 14 | 27 | 35 | 11 | 13 |
| | 90-105 | 13 | 17 | 35 | 9 | 11 |
| | 105-120 | 12 | 16 | 28 | 5 | 10 |
| | 120-135 | 11 | 16 | 22 | 5 | 10 |
| | 135-150 | 12 | 16 | 21 | 4 | 10 |
| | 150-165 | 12 | 17 | 20 | 5 | 11 |
| | 165-180 | 13 | 16 | 17 | NS | 15 |
| | 180-195 | 13 | 14 | 17 | NS | 10 |
| | 195-210 | 12 | 11 | 15 | NS | 10 |
| | 210-225 | 10 | 13 | 16 | NS | 11 |
| Apr. '77 | 0-15 | 59 | 33 | 28 | NS | 29 |
| | 15-30 | 27 | 20 | 18 | NS | 7 |
| | 30-45 | 17 | 16 | 21 | NS | 10 |
| | 45-60 | 19 | 28 | 22 | NS | 14 |
| | 60-75 | 11 | 30 | 23 | NS | 12 |
| | 75-90 | 11 | 31 | 34 | NS | 10 |
| | 90-105 | 13 | 22 | 40 | 12 | 10 |
| | 105-120 | 11 | 18 | 36 | 7 | 9 |
| | 120-135 | 11 | 20 | 29 | 4 | 12 |
| | 135-150 | 12 | 19 | 24 | 6 | 13 |
| | 150-165 | 11 | 18 | 17 | NS | 11 |
| | 165-180 | 11 | 18 | 21 | NS | 10 |
| | 180-195 | 10 | 14 | 17 | 5 | 10 |
| | 195-210 | 9 | 11 | 15 | NS | 10 |
| | 210-225 | -- | 9 | 17 | -- | 13 |
| Dec. '77 | 0-15 | 51 | 28 | 32 | NS | 36 |
| | 15-30 | 31 | 20 | 12 | 12 | 9 |
| | 30-45 | 22 | 13 | 15 | NS | 15 |
| | 45-60 | 20 | 26 | 18 | NS | 15 |
| | 60-75 | 15 | 36 | 29 | NS | 26 |
| | 75-90 | 12 | 33 | 34 | NS | 21 |
| | 90-105 | 10 | 38 | 35 | 19 | 14 |
| | 105-120 | 11 | 26 | 53 | 14 | 23 |
| | 120-135 | 10 | 25 | 38 | 12 | 14 |
| | 135-150 | 11 | 18 | 33 | 11 | 16 |
| | 150-165 | 12 | 21 | 24 | 3 | 12 |
| | 165-180 | 14 | 16 | 22 | 5 | 19 |
| | 180-195 | 15 | 16 | 22 | NS | 21 |
| | 195-210 | 12 | 15 | 30 | 13 | 21 |
| Apr. '78 | 0-15 | 53 | 29 | 44 | NS | 25 |
| | 15-30 | 38 | 21 | 14 | 18 | 4 |
| | 30-45 | 29 | 27 | 16 | 11 | 8 |
| | 45-60 | 25 | 39 | 25 | NS | 23 |
| | 60-75 | 20 | 36 | 30 | NS | 21 |
| | 75-90 | 17 | 37 | 34 | NS | 15 |
| | 90-105 | 17 | 30 | 42 | 16 | 15 |
| | 105-120 | 16 | 28 | 38 | 8 | 16 |
| | 120-135 | 15 | 24 | 35 | 9 | 14 |
| | 135-150 | 15 | 19 | 30 | 7 | 13 |
| | 150-165 | 12 | 16 | 26 | 6 | 13 |
| | 165-180 | 13 | 15 | 23 | 7 | 12 |
| | 180-195 | 12 | 14 | 23 | 8 | 13 |
| | 195-210 | 13 | 13 | 25 | 8 | 13 |

(Continued)

TABLE C-5. (continued)

| Sampling date | Depth | Effluent application rate<br>Low | <br>Medium | <br>High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------ppm, dry soil basis---------- | | | | |
| Oct. '78 | 0-15 | 49 | 27 | 16 | 13 | 14 |
| | 15-30 | 28 | 20 | 11 | NS | 9 |
| | 30-45 | 21 | 18 | 17 | NS | 16 |
| | 45-60 | 20 | 23 | 22 | NS | 14 |
| | 60-75 | 17 | 29 | 33 | NS | 15 |
| | 75-90 | 15 | 32 | 33 | 11 | 13 |
| | 90-105 | 12 | 25 | 36 | 11 | 13 |
| | 105-120 | 13 | 20 | 36 | 12 | 13 |
| | 120-135 | 12 | 15 | 27 | 4 | 11 |
| | 135-150 | 11 | 16 | 23 | 9 | 10 |
| | 150-165 | 11 | 13 | 22 | 9 | 10 |
| | 165-180 | 11 | 13 | 20 | 7 | 9 |
| | 180-195 | 11 | 10 | 15 | NS | 10 |
| | 195-210 | 10 | 9 | 15 | NS | 10 |
| | 210-225 | 10 | 9 | 13 | NS | 8 |
| | 225-240 | 9 | 10 | 11 | NS | 7 |
| | 240-255 | 8 | 8 | 11 | NS | 6 |
| | 255-270 | 8 | 7 | 10 | NS | 7 |
| | 270-285 | 8 | 9 | 10 | NS | 6 |
| | 285-300 | 8 | 9 | 10 | NS | 10 |
| | 300-315 | 8 | 8 | 10 | NS | 9 |
| | 315-330 | 10 | 7 | 10 | NS | 8 |

* The control treatment was not replicated so it cannot be statistically compared with the effluent treatment.

** Differences are not significant.

TABLE C-6. EFFECT OF SWINE MANURE LAGOON EFFLUENT ON DILUTE ACID EXTRACTABLE SOIL Na

| Sampling date | Depth | Effluent application rate | | | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | | Low | Medium | High | | |
| | cm | ----------ppm, dry soil basis---------- | | | | |
| Dec. '73 | 0-15 | 12 | 6 | 20 | NS | -- |
| | 15-30 | 11 | 13 | 14 | NS | -- |
| | 30-45 | 12 | 14 | 20 | NS | -- |
| | 45-60 | 13 | 17 | 18 | NS | -- |
| | 60-75 | 15 | 19 | 23 | NS | -- |
| Mar. '74 | 0-15 | 11 | 10 | 10 | NS | -- |
| | 15-30 | 13 | 12 | 11 | NS | -- |
| | 30-45 | 13 | 16 | 17 | NS | -- |
| | 45-60 | 15 | 22 | 21 | NS | -- |
| | 60-75 | 16 | 28 | 21 | 9. | -- |
| June '74 | 0-15 | 23 | 23 | 26 | NS | -- |
| | 15-30 | 15 | 20 | 25 | 3 | -- |
| | 30-45 | 16 | 20 | 23 | 4 | -- |
| | 45-60 | 17 | 21 | 24 | 4 | -- |
| | 60-75 | 16 | 26 | 26 | NS | -- |
| Sept. '74 | 0-15 | 18 | 15 | 15 | NS | -- |
| | 15-30 | 13 | 12 | 12 | NS | -- |
| | 30-45 | 13 | 12 | 14 | NS | -- |
| | 45-60 | 16 | 16 | 19 | NS | -- |
| | 60-75 | 19 | 22 | 24 | NS | -- |
| July '75 | 0-15 | 20 | 21 | 22 | NS | 20 |
| | 15-30 | 16 | 14 | 13 | 4 | 15 |
| | 30-45 | 25 | 19 | 28 | NS | 18 |
| | 45-60 | 30 | 27 | 34 | NS | 26 |
| | 60-75 | 29 | 32 | 40 | NS | 20 |
| | 75-90 | 30 | 35 | 42 | NS | 29 |
| | 90-105 | 31 | 35 | 41 | 5 | 24 |
| | 105-120 | 13 | 12 | 26 | NS | 21 |
| Dec. '75 | 0-15 | 9 | 6 | 6 | NS | 6 |
| | 15-30 | 16 | 8 | 8 | NS | 3 |
| | 30-45 | 24 | 17 | 10 | NS | 4 |
| | 45-60 | 26 | 22 | 20 | NS | 10 |
| | 60-75 | 28 | 29 | 29 | NS | 12 |
| | 75-90 | 23 | 33 | 31 | NS | 9 |
| | 90-105 | 16 | 34 | 30 | NS | 6 |
| | 105-120 | 12 | 29 | 37 | 16 | 7 |
| | 120-135 | 10 | 23 | 32 | 9 | 7 |
| | 135-150 | 8 | 17 | 28 | 14 | 6 |
| | 150-165 | 9 | 14 | 29 | 9 | 6 |
| | 165-180 | 7 | 13 | 28 | 8 | 7 |
| | 180-195 | 9 | 12 | 26 | 12 | 7 |
| | 195-210 | 8 | 10 | 27 | 13 | 8 |
| | 210-225 | | 11 | 24 | NS | 6 |
| Apr. '76 | 0-15 | 15 | 14 | 13 | NS | 13 |
| | 15-30 | 19 | 14 | 13 | NS | 14 |
| | 30-45 | 24 | 19 | 14 | NS | 15 |
| | 45-60 | 28 | 24 | 16 | NS | 16 |
| | 60-75 | 28 | 31 | 21 | NS | 17 |
| | 75-90 | 28 | 31 | 27 | NS | 16 |
| | 90-105 | 28 | 35 | 29 | NS | 16. |
| | 105-120 | 14 | 16 | 30 | NS | 17 |
| | 120-135 | 21 | 32 | 34 | 8 | 17 |
| | 135-150 | 19 | 29 | 35 | 7 | 16 |
| | 150-165 | 17 | 27 | 34 | 5 | 16 |
| | 165-180 | 17 | 24 | 36 | 10 | 21 |
| | 180-195 | 16 | 21 | 34 | 6 | 23 |
| | 195-210 | 17 | 21 | 28 | 8 | 19 |

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TABLE C-6. (continued)

| Sampling date | Depth | Effluent application rate Low | Medium | High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------ppm, dry soil basis---------- | | | | |
| Nov. '76 | 0-15 | 9 | 4 | 4 | 4 | 7 |
| | 15-30 | 12 | 5 | 5 | 4 | 3 |
| | 30-45 | 28 | 13 | 13 | NS | 6 |
| | 45-60 | 38 | 34 | 28 | NS | 5 |
| | 60-75 | 35 | 36 | 33 | NS | 13 |
| | 75-90 | 32 | 50 | 39 | 7 | 15 |
| | 90-105 | 26 | 45 | 41 | NS | 15 |
| | 105-120 | 21 | 32 | 35 | NS | 14 |
| | 120-135 | 17 | 28 | 31 | NS | 12 |
| | 135-150 | 15 | 27 | 25 | NS | 12 |
| | 150-165 | 15 | 24 | 26 | NS | 13 |
| | 165-180 | 15 | 24 | 29 | NS | 12 |
| | 180-195 | 14 | 23 | 39 | 9 | 13 |
| | 195-210 | 14 | 22 | 34 | NS | 12 |
| | 210-225 | 13 | 21 | 33 | 8 | 11 |
| Apr. '77 | 0-15 | 11 | 10 | 9 | NS | 9 |
| | 15-30 | 12 | 10 | 9 | NS | 8 |
| | 30-45 | 16 | 9 | 10 | NS | 10 |
| | 45-60 | 24 | 11 | 12 | NS | 12 |
| | 60-75 | 22 | 20 | 13 | NS | 12 |
| | 75-90 | 24 | 23 | 17 | NS | 13 |
| | 90-105 | 48 | 38 | 19 | NS | 12 |
| | 105-120 | 25 | 32 | 27 | NS | 12 |
| | 120-135 | 21 | 28 | 23 | NS | 13 |
| | 135-150 | 20 | 25 | 28 | NS | 14 |
| | 150-165 | 14 | 23 | 25 | NS | 12 |
| | 165-180 | 13 | 23 | 24 | 6 | 12 |
| | 180-195 | 13 | 21 | 24 | 6 | 12 |
| | 195-210 | 13 | 17 | 24 | 6 | 12 |
| | 210-225 | -- | 14 | 40 | -- | 14 |
| Dec. '77 | 0-15 | 10 | 26 | 10 | NS | 7 |
| | 15-30 | 12 | 34 | 11 | NS | 5 |
| | 30-45 | 13 | 33 | 12 | NS | 6 |
| | 45-60 | 22 | 10 | 15 | NS | 8 |
| | 60-75 | 28 | 16 | 18 | NS | 10 |
| | 75-90 | 27 | 22 | 22 | NS | 10 |
| | 90-105 | 28 | 30 | 25 | NS | 8 |
| | 105-120 | 27 | 35 | 31 | NS | 10 |
| | 120-135 | 18 | 34 | 33 | NS | 7 |
| | 135-150 | 14 | 29 | 26 | NS | 8 |
| | 150-165 | 14 | 26 | 26 | NS | 6 |
| | 165-180 | 14 | 30 | 27 | NS | 6 |
| | 180-195 | 17 | 24 | 28 | 8 | 7 |
| | 195-210 | 15 | 24 | 27 | 5 | 8 |
| Apr. '78 | 0-15 | 5 | 7 | 6 | NS | 2 |
| | 15-30 | 6 | 5 | 7 | NS | 1 |
| | 30-45 | 11 | 7 | 9 | NS | 2 |
| | 45-60 | 18 | 9 | 11 | NS | 8 |
| | 60-75 | 26 | 12 | 14 | NS | 13 |
| | 75-90 | 28 | 19 | 16 | NS | 9 |
| | 90-105 | 34 | 28 | 18 | NS | 6 |
| | 105-120 | 29 | 31 | 20 | NS | 5 |
| | 120-135 | 24 | 29 | 22 | NS | 4 |
| | 135-150 | 21 | 29 | 23 | NS | 4 |
| | 150-165 | 16 | 24 | 25 | 6 | 3 |
| | 165-180 | 14 | 25 | 25 | 7 | 3 |
| | 180-195 | 13 | 22 | 27 | 8 | 4 |
| | 195-210 | 13 | 21 | 23 | NS | 4 |

(Continued)

TABLE C-6. (continued)

| Sampling date | Depth | Effluent application rate Low | Effluent application rate Medium | Effluent application rate High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
|  | cm | ----------ppm, dry soil basis---------- |  |  |  |  |
| Oct. '78 | 0-15 | 26 | 25 | 25 | NS | 22 |
|  | 15-30 | 20 | 24 | 22 | NS | 5 |
|  | 30-45 | 16 | 12 | 20 | NS | 21 |
|  | 45-60 | 18 | 16 | 25 | NS | 16 |
|  | 60-75 | 27 | 20 | 28 | NS | 15 |
|  | 75-90 | 33 | 26 | 29 | NS | 17 |
|  | 90-105 | 30 | 26 | 29 | NS | 18 |
|  | 105-120 | 32 | 29 | 26 | NS | 16 |
|  | 120-135 | 23 | 29 | 25 | NS | 15 |
|  | 135-150 | 22 | 29 | 27 | NS | 14 |
|  | 150-165 | 20 | 26 | 29 | NS | 15 |
|  | 165-180 | 21 | 25 | 34 | NS | 13 |
|  | 180-195 | 19 | 27 | 35 | NS | 16 |
|  | 195-210 | 22 | 25 | 36 | 7 | 18 |
|  | 210-225 | 21 | 27 | 40 | 9 | 17 |
|  | 225-240 | 21 | 25 | 38 | 6 | 14 |
|  | 240-255 | 18 | 24 | 33 | 11 | 11 |
|  | 255-270 | 19 | 23 | 30 | 6 | 14 |
|  | 270-285 | 21 | 23 | 27 | NS | 13 |
|  | 285-300 | 19 | 24 | 28 | NS | 13 |
|  | 300-315 | 18 | 21 | 26 | NS | 13 |
|  | 315-330 | 20 | 22 | 25 | NS | 13 |

* The control treatment was not replicated so it cannot be statistically compared with the effluent treatments.

** Differences are not significant.

## TABLE C-7. EFFECT OF SWINE MANURE LAGOON EFFLUENT ON DILUTE ACID EXTRACTABLE SOIL Zn

| Sampling date | Depth | Effluent application rate Low | Medium | High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------ppm, dry soil basis---------- | | | | |
| Dec. '73 | 0-8 | 4.12 | 3.57 | 4.47 | NS | -- |
| | 8-15 | 3.12 | 2.00 | 4.30 | NS | -- |
| | 15-30 | 2.49 | 2.29 | 4.57 | NS | -- |
| | 30-45 | 2.48 | 1.90 | 2.47 | NS | -- |
| | 45-60 | 2.06 | 2.11 | 1.99 | NS | -- |
| | 60-75 | 1.24 | 2.56 | 2.40 | NS | -- |
| | 75-90 | 1.69 | 1.67 | 2.25 | NS | -- |
| July '75 | 0-8 | 2.50 | 2.62 | 3.30 | NS | 1.00 |
| | 8-15 | 1.10 | 1.40 | 1.21 | NS | .47 |
| | 15-30 | .83 | .83 | .77 | NS | .33 |
| | 30-45 | .88 | .99 | .74 | NS | .40 |
| | 45-60 | .73 | .73 | 1.16 | NS | .87 |
| | 60-75 | .91 | .81 | .63 | NS | .60 |
| | 75-90 | .73 | .72 | .88 | NS | .67 |
| Nov. '76 | 0-8 | 4.1 | 3.2 | 5.6 | NS | 9.8 |
| | 8-15 | 1.77 | 2.20 | 2.50 | NS | 12.6 |
| | 15-30 | 3.10 | 2.93 | 3.63 | NS | 1.1 |
| | 30-45 | 2.20 | 1.47 | 3.27 | NS | 3.3 |
| | 45-60 | -- | -- | -- | -- | 0 |
| | 60-75 | -- | -- | -- | -- | 0 |
| Dec. '77 | 0-8 | 2.90 | 3.47 | 2.90 | NS | 7.5 |
| | 8-15 | 5.10 | 2.20 | 2.80 | NS | .5 |
| | 15-30 | 1.90 | 3.53 | 3.03 | NS | 2.8 |
| | 30-45 | .73 | 1.40 | 3.13 | NS | .8 |
| | 45-60 | 3.43 | 2.67 | 1.27 | NS | 6.2 |
| | 60-75 | 1.53 | 1.77 | 1.97 | NS | 1.7 |
| Oct. '78 | 0-8 | 2.50 | 1.87 | 1.70 | NS | 1.2 |
| | 8-15 | .93 | 2.13 | 1.33 | .64 | 1.1 |
| | 15-30 | .70 | .73 | .93 | NS | .5 |
| | 30-45 | .50 | .77 | 1.20 | NS | .5 |
| | 45-60 | .90 | .60 | .60 | NS | 1.0 |
| | 60-75 | .47 | .47 | .57 | NS | .4 |

* The control treatment was not replicated so it cannot be statistically compared with the effluent treatments.

TABLE C-8. EFFECT OF SWINE MANURE LAGOON EFFLUENT ON DILUTE ACID EXTRACTABLE SOIL Cu

| Sampling date | Depth | Effluent application rate<br>Low | Medium | High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------ppm, dry soil basis----------- | | | | |
| Dec. '73 | 0-8 | 2.80 | 1.28 | 2.41 | NS** | -- |
| | 8-15 | 1.28 | 1.01 | 2.43 | NS | -- |
| | 15-30 | .88 | 1.06 | 1.85 | NS | -- |
| | 30-45 | .72 | .88 | 1.48 | NS | -- |
| | 45-60 | .66 | .74 | 1.22 | NS | -- |
| | 60-75 | .74 | .68 | 1.00 | NS | -- |
| | 75-90 | .81 | .70 | 1.15 | .33 | -- |
| Mar. '74 | 0-8 | 2.54 | 2.38 | 2.33 | NS | -- |
| | 8-15 | 2.41 | 2.09 | 3.11 | NS | -- |
| | 15-30 | 2.66 | 2.69 | 3.78 | NS | -- |
| | 30-45 | 2.38 | 2.03 | 3.97 | NS | -- |
| | 45-60 | 2.05 | 1.72 | 3.20 | NS | -- |
| | 60-75 | 2.07 | 2.15 | 4.38 | NS | -- |
| | 75-90 | 2.11 | 2.26 | 3.18 | NS | -- |
| June '74 | 0-8 | 1.01 | 1.34 | 1.53 | NS | -- |
| | 8-15 | .93 | .94 | 1.03 | NS | -- |
| | 15-30 | .92 | .99 | 1.11 | NS | -- |
| | 30-45 | .94 | .94 | 1.50 | .2 | -- |
| | 45-60 | .75 | .89 | 1.14 | .26 | -- |
| | 60-75 | .84 | .99 | 1.60 | NS | -- |
| | 75-90 | 1.12 | 1.13 | 1.23 | NS | -- |
| Sept. '74 | 0-8 | .77 | .78 | 1.37 | .30 | -- |
| | 8-15 | .61 | .47 | .80 | NS | -- |
| | 15-30 | .64 | .51 | .48 | .10 | -- |
| | 30-45 | .52 | .55 | .52 | NS | -- |
| | 45-60 | .72 | .57 | .59 | NS | -- |
| | 60-75 | .93 | .85 | .76 | NS | -- |
| | 75-90 | 1.54 | 1.16 | 1.42 | NS | -- |
| July '75 | 0-8 | .74 | 1.14 | 1.40 | 0.14 | .49 |
| | 8-15 | .32 | .47 | .56 | 0.16 | .36 |
| | 15-30 | .27 | .38 | .32 | NS | .38 |
| | 30-45 | .32 | .29 | .32 | NS | .41 |
| | 45-60 | .31 | .36 | .30 | NS | .51 |
| | 60-75 | .28 | .32 | .45 | NS | .52 |
| | 75-90 | .33 | .47 | .45 | NS | .47 |

(Continued)

TABLE C-8. (continued)

| Sampling date | Depth | Effluent application rate<br>Low | <br>Medium | <br>High | $LSD_{0.05}$ | Control* |
|---|---|---|---|---|---|---|
| | cm | ---------ppm, dry soil basis------------ | | | | |
| Nov. '76 | 0-8 | .68 | 1.01 | 1.91 | NS | .24 |
| | 8-15 | .29 | .47 | 1.00 | .54 | .36 |
| | 15-30 | .33 | .27 | .69 | NS | .16 |
| | 30-45 | .25 | .25 | .48 | .15 | .32 |
| | 45-60 | .13 | .20 | .19 | NS | .24 |
| | 60-75 | .16 | .19 | .16 | NS | .20 |
| Dec. '77 | 0-8 | .75 | 1.21 | 1.61 | .39 | .28 |
| | 8-15 | .35 | .55 | .76 | .21 | .20 |
| | 15-30 | .31 | .23 | .49 | NS | .24 |
| | 30-45 | .21 | .60 | .39 | NS | .20 |
| | 45-60 | .16 | .21 | .29 | .09 | .12 |
| | 60-75 | .15 | .19 | .25 | NS | .20 |
| Oct. '78 | 0-8 | .56 | .88 | 1.12 | .30 | .36 |
| | 8-15 | .35 | .47 | .69 | .26 | .24 |
| | 15-30 | .19 | .39 | .40 | NS | .20 |
| | 30-45 | .17 | .20 | .29 | NS | .16 |
| | 45-60 | .17 | .17 | .23 | NS | .36 |
| | 60-75 | .13 | .20 | .25 | NS | .28 |
| | 75-90 | .13 | .15 | .16 | NS | .20 |

* The control treatment was not replicated so it cannot be statistically compared with effluent treatments.

** Differences are not significant.

## TABLE C-9. EFFECT OF SWINE MANURE LAGOON EFFLUENT ON SOIL pH

| Sampling date | Depth | Effluent application rate Low | Medium | High | | Control* |
|---|---|---|---|---|---|---|
| | cm | pH | | | | |
| Dec. '73 | 0-15 | 5.9 | 5.8 | 5.8 | NS** | -- |
| | 15-30 | 5.3 | 5.4 | 5.2 | NS | -- |
| | 30-45 | 5.2 | 5.4 | 5.2 | NS | -- |
| | 45-60 | 5.0 | 5.1 | 5.0 | NS | -- |
| | 60-75 | 4.8 | 5.0 | 4.8 | NS | -- |
| Mar. '74 | 0-15 | 4.8 | 5.1 | 5.3 | NS | -- |
| | 15-30 | 4.4 | 4.6 | 4.7 | NS | -- |
| | 30-45 | 4.4 | 4.3 | 4.6 | NS | -- |
| | 45-60 | 4.2 | 4.2 | 4.6 | NS | -- |
| | 60-75 | 3.9 | 4.2 | 4.5 | NS | -- |
| June '74 | 0-15 | 6.0 | 5.7 | 5.3 | NS | -- |
| | 15-30 | 5.2 | 5.2 | 5.0 | NS | -- |
| | 30-45 | 5.1 | 5.2 | 4.8 | NS | -- |
| | 45-60 | 5.1 | 5.2 | 4.7 | NS | -- |
| | 60-75 | 5.0 | 5.0 | 4.6 | NS | -- |
| Sept. '74 | 0-15 | 5.9 | 5.6 | 5.4 | NS | -- |
| | 15-30 | 5.4 | 5.3 | 5.4 | NS | -- |
| | 30-45 | 5.3 | 5.0 | 5.0 | NS | -- |
| | 45-60 | 5.1 | 4.7 | 4.7 | NS | -- |
| | 60-75 | 4.8 | 4.6 | 4.5 | NS | -- |
| July '75 | 0-15 | 5.8a*** | 5.5b | 5.5b | | 5.7 |
| | 15-30 | 5.6 | 5.5 | 5.4 | NS | 5.0 |
| | 30-45 | 5.4 | 5.3 | 5.1 | NS | 5.0 |
| | 45-60 | 5.3 | 5.0 | 4.8 | NS | 5.2 |
| | 60-75 | 5.0 | 4.8 | 4.5 | NS | 5.5 |
| | 75-90 | 5.2 | 5.0 | 4.5 | NS | 5.3 |
| | 90-105 | 5.2 | 5.0 | 4.7 | NS | 5.4 |
| | 105-120 | 5.3a | 5.1ab | 4.8b | | 5.2 |
| Dec. '75 | 0-15 | 6.0a | 5.5ab | 5.2b | | 5.6 |
| | 15-30 | 5.7 | 5.5 | 5.4 | NS | 5.0 |
| | 30-45 | 5.4 | 5.1 | 5.0 | NS | 4.7 |
| | 45-60 | 5.2 | 4.8 | 4.7 | NS | 4.9 |
| | 60-75 | 4.9 | 4.8 | 4.5 | NS | 5.0 |
| | 75-90 | 4.9a | 4.7a | 4.3b | | 5.0 |
| | 90-105 | 4.9a | 4.8a | 4.3b | | 4.9 |
| | 105-120 | 4.7a | 4.7a | 4.3b | | 4.9 |
| | 120-135 | 4.6 | 4.6 | 4.4 | NS | 4.8 |
| | 135-150 | 4.6 | 4.6 | 4.4 | NS | 4.9 |
| | 150-165 | 4.6 | 4.6 | 4.5 | NS | 4.8 |
| | 165-180 | 4.6 | 4.6 | 4.5 | NS | 4.8 |
| | 180-195 | 4.6 | 4.7 | 4.6 | NS | 4.8 |
| | 195-210 | 4.6 | 4.7 | 4.6 | NS | 4.8 |
| | 210-225 | 4.7 | 4.7 | 4.6 | NS | 4.7 |
| Apr. '76 | 0-15 | 6.0a | 5.7b | 5.2b | | 5.6 |
| | 15-30 | 5.6 | 5.5 | 5.4 | NS | 5.1 |
| | 30-45 | 5.4 | 5.3 | 5.3 | NS | 5.0 |
| | 45-60 | 5.3 | 5.2 | 5.0 | NS | 5.1 |
| | 60-75 | 5.1 | 5.0 | 4.7 | NS | 5.2 |
| | 75-90 | 5.1a | 5.0a | 4.6b | | 5.1 |
| | 90-105 | 5.1a | 4.8a | 4.5b | | 5.1 |
| | 105-120 | 5.0a | 4.8a | 4.4b | | 5.0 |
| | 120-135 | 4.9 | 4.8 | 4.5 | NS | 4.9 |
| | 135-150 | 4.8a | 4.8a | 4.5b | | 5.0 |
| | 150-165 | 4.7a | 4.7a | 4.5b | | 5.0 |
| | 165-180 | 4.7 | 4.7 | 4.6 | NS | 5.1 |
| | 180-195 | 4.7 | 4.8 | 4.8 | NS | 5.1 |
| | 195-210 | 4.7 | 4.8 | 4.7 | NS | 5.0 |

(Continued)

TABLE C-9. (continued)

| Sampling date | Depth | Effluent application rate Low | Effluent application rate Medium | Effluent application rate High |  | Control* |
|---|---|---|---|---|---|---|
|  | cm | pH |  |  |  |  |
| Nov. '76 | 0-15 | 5.9 | 5.3 | 4.8 | NS | 5.4 |
|  | 15-30 | 5.6a | 5.5a | 4.8b |  | 5.1 |
|  | 30-45 | 5.6 | 4.7 | 4.8 | NS | 4.9 |
|  | 45-60 | 5.2a | 4.7ab | 4.6b |  | 5.2 |
|  | 60-75 | 5.0a | 4.6a | 4.3b |  | 5.3 |
|  | 75-90 | 5.2a | 4.8b | 4.4c |  | 5.2 |
|  | 90-105 | 5.2a | 4.9a | 4.3b |  | 4.9 |
|  | 105-120 | 5.1a | 4.8a | 4.4b |  | 4.9 |
|  | 120-135 | 4.9a | 4.8a | 4.4b |  | 4.9 |
|  | 135-150 | 4.8a | 4.7a | 4.4b |  | 5.0 |
|  | 150-165 | 4.8 | 4.6 | 4.3 | NS | 5.0 |
|  | 165-180 | 4.8 | 4.7 | 4.4 | NS | 5.0 |
|  | 180-195 | 4.7 | 4.7 | 4.3 | NS | 4.9 |
|  | 195-210 | 4.7 | 4.6 | 4.5 | NS | 4.9 |
|  | 210-225 | 4.9 | 4.8 | 4.6 | NS | 5.0 |
| Apr. '77 | 0-15 | 5.8 | 5.5 | 4.9 | NS | 5.3 |
|  | 15-30 | 5.6 | 5.4 | 5.0 | NS | 4.9 |
|  | 30-45 | 5.2a | 5.2a | 5.1b |  | 4.8 |
|  | 45-60 | 5.0 | 4.7 | 4.8 | NS | 4.9 |
|  | 60-75 | 4.7 | 4.6 | 4.7 | NS | 5.0 |
|  | 75-90 | 4.9 | 4.7 | 4.6 | NS | 4.9 |
|  | 90-105 | 4.9a | 4.7a | 4.4b |  | 4.9 |
|  | 105-120 | 4.8a | 4.7a | 4.3b |  | 4.8 |
|  | 120-135 | 4.8 | 4.7 | 4.5 | NS | 4.9 |
|  | 135-150 | 4.8 | 4.6 | 4.5 | NS | 4.8 |
|  | 150-165 | 4.7 | 4.6 | 4.4 | NS | 4.8 |
|  | 165-180 | 4.6 | 4.6 | 4.4 | NS | 4.9 |
|  | 180-195 | 4.7 | 4.6 | 4.5 | NS | 4.7 |
|  | 195-210 | 4.7 | 4.6 | 4.4 | NS | 4.8 |
|  | 210-225 | -- | 4.6 | 4.4 | -- | 4.8 |
| Dec. '77 | 0-15 | 5.8 | 4.6 | 4.5 | NS | 5.5 |
|  | 15-30 | 5.6 | 5.5 | 4.8 | NS | 4.8 |
|  | 30-45 | 5.1 | 5.3 | 4.9 | NS | 4.4 |
|  | 45-60 | 5.1 | 4.8 | 4.8 | NS | 4.7 |
|  | 60-75 | 5.0 | 4.7 | 4.7 | NS | 4.7 |
|  | 75-90 | 5.0 | 4.6 | 4.5 | NS | 4.7 |
|  | 90-105 | 4.9 | 4.6 | 4.3 | NS | 4.6 |
|  | 105-120 | 4.9 | 4.6 | 4.3 | NS | 4.5 |
|  | 120-135 | 4.7 | 4.6 | 4.3 | NS | 4.5 |
|  | 135-150 | 4.6 | 4.5 | 4.3 | NS | 4.5 |
|  | 150-165 | 4.6a | 4.6a | 4.3b |  | 4.4 |
|  | 165-180 | 4.6a | 4.6a | 4.4b |  | 4.4 |
|  | 180-195 | 4.6 | 4.6 | 4.3 | NS | 4.3 |
|  | 195-210 | 4.6 | 4.6 | 4.3 | NS | 4.2 |
| Apr. '78 | 0-15 | 5.1 | 4.3 | 4.3 | NS | 4.8 |
|  | 15-30 | 4.7a | 4.6a | 4.5b |  | 4.3 |
|  | 30-45 | 4.5 | 4.4 | 4.5 | NS | 4.2 |
|  | 45-60 | 4.3 | 4.3 | 4.3 | NS | 4.0 |
|  | 60-75 | 4.2 | 4.0 | 4.1 | NS | 4.2 |
|  | 75-90 | 4.2 | 4.0 | 3.9 | NS | 4.2 |
|  | 90-105 | 4.3a | 3.9b | 3.8c |  | 4.1 |
|  | 105-120 | 4.1 | 3.9 | 3.8 | NS | 4.0 |
|  | 120-135 | 4.1a | 4.0a | 3.8b |  | 3.8 |
|  | 135-150 | 4.0a | 4.0a | 3.7b |  | 4.0 |
|  | 150-165 | 3.8 | 3.9 | 3.8 | NS | 3.8 |
|  | 165-180 | 3.9 | 3.9 | 3.8 | NS | 4.0 |
|  | 180-195 | 3.9 | 3.8 | 3.8 | NS | 3.9 |
|  | 195-210 | 3.9 | 3.9 | 3.9 | NS | 4.0 |

(Continued)

TABLE C-9. (continued)

| Sampling date | Depth | Effluent application rate<br>Low | <br>Medium | <br>High | | Control* |
|---|---|---|---|---|---|---|
| | cm | ----------------------- | pH | ----------------------- | | |
| Oct. '78 | 0-15 | 5.9 | 4.9 | 4.3 | NS | 5.5 |
| | 15-30 | 5.8 | 5.3 | 4.5 | NS | 5.3 |
| | 30-45 | 5.5 | 4.9 | 4.9 | NS | 4.9 |
| | 45-60 | 5.4 | 4.9 | 4.8 | NS | 5.0 |
| | 60-75 | 5.1 | 4.5 | 4.6 | NS | 5.0 |
| | 75-90 | 5.0 | 4.5 | 4.5 | NS | 5.1 |
| | 90-105 | 5.0 | 4.5 | 4.4 | NS | 5.0 |
| | 105-120 | 5.0a | 4.6ab | 4.4b | | 4.8 |
| | 120-135 | 4.7 | 4.5 | 4.2 | NS | 4.7 |
| | 135-150 | 4.7 | 4.5 | 4.3 | NS | 4.7 |
| | 150-165 | 4.7 | 4.4 | 4.2 | NS | 4.7 |
| | 165-180 | 4.6 | 4.4 | 4.4 | NS | 4.7 |
| | 180-195 | 4.6 | 4.5 | 4.5 | NS | 4.8 |
| | 195-210 | 4.6 | 4.5 | 4.4 | NS | 4.7 |
| | 210-225 | 4.4 | 4.4 | 4.3 | NS | 4.9 |
| | 225-240 | 4.5 | 4.3 | 4.4 | NS | 4.9 |
| | 240-255 | 4.3 | 4.3 | 4.4 | NS | 4.9 |
| | 255-270 | 4.3 | 4.3 | 4.4 | NS | 4.8 |
| | 270-285 | 4.4 | 4.3 | 4.2 | NS | 4.8 |
| | 285-300 | 4.3 | 4.3 | 4.3 | NS | 4.8 |
| | 300-315 | 4.3 | 4.3 | 4.2 | NS | 4.9 |
| | 315-330 | 4.4 | 4.3 | 4.2 | NS | 4.9 |

* The control treatment was not replicated so it cannot be statistically compared with the effluent treatments.

** Differences are not significant.

*** Values at the same depth followed by the same letter are not significantly different at the 5% level.

# APPENDIX D

# IRRIGATION AND RAINFALL-IRRIGATION MIXED RUNOFF VOLUMES BY EVENT

## TABLE D-1. IRRIGATION RUNOFF

| Date | Runoff amount, cm |  |  |  |  |  |  |  |  | Two-day antecedent rainfall (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
|  | High application plots |  |  | Medium application plots |  |  | Low application plots |  |  |  |
|  | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 |  |
| 730420 |  | 0.15 |  |  |  | 0.10 |  |  |  | 0 |
| 0501 |  | 0.65 |  |  |  | 0.13 |  |  |  | 0 |
| 0508 |  | 0.68 |  | 0.05 |  | 0.33 | 0.12 |  |  | 0 |
| 0515 | 0.10 | 0.38 | 0.10 |  |  | 0.26 |  |  |  | 0.88 |
| 0522 | 0.62 | 0.24 | 1.44 | 0.30 | 0.13 | 0.34 | 0.12 |  |  | 3.14 |
| 0606 | 0.11 | 0.04 |  |  |  | 0.18 | 0.06 |  | 0.10 | 0.50 |
| 0613 |  | 0.13 |  |  |  | 0.10 |  |  |  | 0.20 |
| 0619 | 0.73 | 0.02 |  | 0.37 | 0.04 | 0.05 | 0.03 |  |  | 2.86 |
| 0626 | 0.73 | 0.12 | 0.86 |  |  | 0.06 |  |  |  | 6.69 |
| 0703 |  | 0.06 | 0.08 |  |  |  |  |  |  | 0 |
| 0712 | 0.29 |  |  |  |  |  |  |  |  | 0.53 |
| 0724 | 0.11 |  | 0.04 |  | 0.05 |  |  |  |  | 0 |
| 0814 |  | 0.09 |  |  |  |  |  |  |  | 0.13 |
| 0918 | 0.12 | 0.07 | 0.06 |  |  |  |  |  |  | 0.08 |
| 1973 | 2.81 | 2.63 | 2.58 | 0.72 | 0.22 | 1.55 | 0.33 | - | 0.10 |  |
| 740424 |  | 0.06 | 0.01 |  |  |  |  |  |  | 0.12 |
| 0430 |  | 0.01 |  |  |  |  |  |  |  | 0 |
| 0514 |  | 0.14 | 0.28 |  |  |  |  |  |  | 2.15 |
| 0522 |  | 0.25 |  |  |  |  |  |  |  | 0.30 |
| 0529 |  | 0.08 |  |  |  |  |  |  |  | 0 |
| 0606 |  | 0.60 | 0.03 |  |  |  |  |  |  | 0.05 |
| 0709 | 0.22 | 1.55 |  |  |  |  | 0.16 |  |  | 2.31 |
| 0723 | 0.09 | 0.27 | 0.05 | 0.05 | 0.09 |  | 0.08 |  | 0.08 | 1.29 |
| 0820 | 0.11 |  | 0.51 |  |  |  |  |  |  | 0.05 |
| 1974 | 0.42 | 2.96 | 0.88 | 0.05 | 0.09 | - | 0.24 | - | 0.08 |  |
| 750718 | 0.32 | >0.81$^*$ | 0.03 |  |  | 0.19 |  |  | >0.81$^*$ | 2.27 |
| 750822$^+$ | 0.03 | 0.15 |  |  | 0.01 |  |  |  |  | 0 |
| 1975 | 0.35 | >0.96 | 0.03 | - | 0.01 | 0.19 | - | - | >0.81 |  |

(Continued)

TABLE D-1. (continued)

| Date | Runoff amount, cm | | | | | | | | | Two-day antecedent rainfall (cm) |
|---|---|---|---|---|---|---|---|---|---|---|
| | High application plots | | | Medium application plots | | | Low application plots | | | |
| | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 | |
| 760430 | 0.06 | | 0.02 | | | | | | | 0 |
| 0619 | 0.06 | | | | | | | | 0.84‡ | 2.84 |
| 0709 | | 0.08 | | | | | | | | 0.73 |
| 0827 | | | 0.32 | | | | | | | 0.48 |
| 0911 | | $0.27^{\delta}$ | | | | | | | | 1.60 |
| 1976 | 0.12 | 0.35 | 0.34 | - | - | - | - | - | 0.84 | |
| 770630 | | 0.02 | | | 0.01 | | | | | 5.33 |
| 0710 | | 0.03 | | | 0.03 | | | | | 0 |
| 0716 | | 0.04 | | | 0.03 | | | | | 0.07 |
| 0719 | | 0.05 | | | 0.02 | | | | | 0 |
| 0819 | | 0.02 | | | | | | | | 2.76 |
| 1977 | - | 0.16 | - | - | 0.09 | - | - | - | - | |
| 780510 | | | 0.12 | | | 0.07 | | | 0.29 | 3.47 |
| 0526 | | | | | | | | 0.01 | | 0 |
| 0707 | | | | | 0.06 | | | | | 0 |
| 1978 | - | - | 0.12 | - | 0.06 | 0.07 | - | 0.01 | 0.29 | |

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[*] Collection barrels overflowed.

[+] Plots 6-9 had no runoff collected because in process of installing collection gutter.

[‡] The irrigation nozzle nearest the collection gutter evidently malfunctioned, causing increased runoff.

[δ] Irrigation system was left on overnight by mistake resulting in about 14 cm application to plots 1 and 4.

## TABLE D-2. IRRIGATION-RAINFALL MIXED RUNOFF

| | Runoff amount, cm | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | High application plots | | | Medium application plots | | | Low application plots | | | Event rainfall (cm) | Two-day antecedent rainfall (cm) |
| Date | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 | | |
| 730717 | 0.38 | 0.02 | 0.96 | 0.05 | - | 0.40 | 0.06 | - | 0.43 | 2.13 | 3.17 |
| 740806 | 0.82 | 1.40 | 2.09 | 0.46 | 0.31 | >2.16* | 0.58 | - | 1.46 | 1.95 | 0 |
| 750601 | | 0.30 | | | | 0.04 | | | | 0.27 | 2.18 |
| 0613 | 0.09 | | | | 0.10 | | | | | 1.19 | 0.25 |
| 760604 | 0.05 | | 0.65 | 0.01 | | 0.01 | | | | 1.72 | 3.55 |
| 0704 | 0.03 | | | | | | | | | 0.12 | 0 |
| 0731 | | | 0.45 | | | | | 0.03 | | 0.76 | 0 |
| 1976 | 0.08 | - | 1.10 | 0.01 | - | 0.01 | - | 0.03 | - | | |
| 770629† | | 0.02 | | | 0.04 | | | | | 5.33 | 0 |
| 0722 | | 0.08 | | | 0.07 | | | | 0.01 | 2.41 | 0 |
| 0802 | 0.39 | | | | | | | | | | |
| 1977 | 0.39 | 0.10 | - | - | 0.11 | - | - | - | 0.01 | | |
| 780508 | 0.01 | | | | | >1.99* | | | | 2.94 | 0 |
| 0515 | 0.19 | | | | | | | | | 2.33 | 0 |
| 0529 | | | | | 0.02 | | | | | 0.25 | 0 |
| 0609 | 0.54 | 0.14 | >1.99* | 0.03 | 0.02 | >1.99* | 0.05 | 0.11 | >1.99* | 6.70 | 3.49 |
| 1978 | 0.74 | 0.14 | >1.99 | 0.03 | 0.04 | >3.98 | 0.05 | 0.11 | >1.99 | | |

*Collection barrel overflowed. No adjustments made for overflow.

†This event was clear-water irrigation of 5.33 cm to help new grass sprigs.

# APPENDIX E

## HIGHEST AND MEAN CONCENTRATIONS OF NUTRIENTS AND OTHER POLLUTION PARAMETERS IN RAINFALL RUNOFF FROM EACH PLOT

### NUTRIENTS, TOC AND COD

Tables E-1 through E-7 present the highest concentration event, the mean concentrations (both arithmetic and flow-weighted) and the number of events (total and those which had concentration) for nutrients, TOC and COD for each year. Discussion of these tables was presented in the section on rainfall runoff concentrations.

### METALS OR CATIONS

Annual mean volume-weighted concentrations of Cu and Zn for 1975 through 1977 and of Na, K, Ca, and Mg for 1975 through 1978 are given in Table E-8 for each plot. It is evident that the irrigated plots had much higher mean concentrations than the topdressed plots most years. However, the samples which were analyzed were monthly composite samples and it is suspected that some of the extremely high concentrations resulted from some irrigation-rainfall mixed runoff being erroneously included in the monthly composite sample. Thus, statistical analyses were not performed on this data, but it is obvious that applications of lagoon effluent resulted in increased runoff transport of Na, K, Ca and Mg. Part or most of this effect is due to the increased applications of these materials with lagoon effluent compared to normal fertilization rates with commercial fertilizer.

## TABLE E-1. RAINFALL RUNOFF CONCENTRATIONS - TKN

| | | Highest concentration event[*] | | | Mean concentrations[*,#] | | | Number of events | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Plot[δ] | Concentration, mg/l | Date | Volume, cm | Arith., mg/l | Std. dev., mg/l | Flow-wt., mg/l | With conc. | Total |
| 1973 | 1 | 21 | 6/18 | 0.08 | 6.9 | 6.2 | 3.9 | 7 | 11 |
| | 2 | 7 | 7/16 | 0.34 | 3.9 | 2.5 | 3.1 | 6 | 11 |
| | 3 | 6 | 5/29 | 1.04 | 3.0 | 1.6 | 3.1 | 5 | 7 |
| | 4 | 19 | 11/28 | 0.10 | 6.1 | 6.5 | 3.1 | 5 | 8 |
| | 5 | 16 | 6/18 | 0.11 | 7.2 | 4.9 | 4.6 | 8 | 10 |
| | 6 | 11 | 7/27 | 0.09 | 7.0 | 3.4 | 7.6 | 4 | 6 |
| | 7 | 7 | 5/18 | 0.06 | 3.4 | 1.8 | 2.6 | 6 | 9 |
| | 8 | 11 | 5/29 | 1.71 | 5.0 | 3.2 | 4.6 | 7 | 9 |
| | 9 | 7 | 6/18 | 0.20 | 4.4 | 1.8 | 3.7 | 6 | 9 |
| 1974 | 1 | 76 | 9/3 | 0.45 | 22.9 | 24.3 | 20.0 | 6 | 7 |
| | 2 | 45 | 5/13 | 0.18 | 11.6 | 13.2 | 10.2 | 8 | 11 |
| | 3 | 45 | 9/3 | 0.13 | 17.9 | 19.0 | 5.9 | 3 | 5 |
| | 4 | 31 | 9/3 | 0.65 | 13.9 | 9.9 | 15.5 | 5 | 9 |
| | 5 | 15 | 5/13 | 0.09 | 7.1 | 4.8 | 4.0 | 4 | 8 |
| | 6 | 5 | 11/20 | 0.09 | 2.8 | 1.5 | 2.8 | 3 | 5 |
| | 7 | 66 | 9/3 | 0.65 | 19.6 | 24.4 | 12.6 | 7 | 10 |
| | 8 | 18 | 9/3 | 0.28 | 7.3 | 6.0 | 5.0 | 6 | 11 |
| | 9 | 53 | 9/3 | 2.06 | 13.7 | 19.8 | 16.2 | 5 | 8 |
| | 10 | 4 | 11/20 | 0.22 | 3.9 | 0 | 3.9 | 1 | 1 |
| | 11 | 2 | 11/20 | 0.19 | 2.2 | 0 | 2.2 | 1 | 1 |
| | 12 | 4 | 11/20 | 0.22 | 4.5 | 0 | 4.5 | 1 | 1 |
| | 13 | 2 | 11/20 | 0.17 | 2.2 | 0 | 2.2 | 1 | 1 |
| 1975 | 1 | 32 | 9/1 | 0.26 | 8.8 | 11.2 | 6.8 | 6 | 6 |
| | 2 | 4 | 11/13 | 0.06 | 3.2 | 0.9 | 3.4 | 7 | 7 |
| | 3 | 5 | 9/1 | 0.10 | 2.8 | 1.8 | 1.8 | 4 | 4 |
| | 4 | 18 | 9/1 | 0.53 | 5.7 | 5.5 | 6.3 | 8 | 8 |
| | 5 | 4 | 7/15 | 0.82 | 3.1 | 0.9 | 3.3 | 6 | 6 |
| | 6 | 10 | 9/1 | 0.16 | 4.2 | 3.1 | 3.8 | 8 | 8 |
| | 7 | 91 | 7/19 | 0.06 | 14.1 | 24.1 | 9.4 | 15 | 16 |
| | 8 | 8 | 7/25 | 0.81 | 3.1 | 1.9 | 3.4 | 14 | 15 |
| | 9 | 12 | 9/1 | 0.16 | 5.0 | 3.1 | 4.9 | 11 | 13 |
| | 10 | 18 | 9/1 | 0.16 | 5.0 | 5.2 | 3.4 | 8 | 11 |
| | 11 | 13 | 9/1 | 0.08 | 4.4 | 3.9 | 2.9 | 7 | 9 |
| | 12 | 11 | 9/1 | 0.10 | 4.3 | 3.2 | 3.3 | 9 | 12 |
| | 13 | 13 | 9/1 | 0.06 | 4.7 | 3.7 | 2.9 | 6 | 8 |
| | 100 | - | - | - | - | - | - | 0 | 0 |
| | 110 | - | - | - | - | - | - | 0 | 0 |
| | 120 | 3 | 11/13 | 0.08 | 2.8 | 0 | 2.8 | 1 | 1 |
| | 130 | - | - | - | - | - | - | 0 | 0 |

(Continued)

[*] For rainfall runoff events ≥ 0.05 cm.

[δ] Irrigated plots: High - 1,4,7; Medium - 3,5,9; Low - 2,6,8. Pasture simulation plots: 10,12,100,120. Hay simulation plots: 11,13,110, 130.

[#] Arith. = Arithmetic mean, Std. dev. = Standard deviation, and Flow wt. = Flow-weighted mean for events which had concentration data and flow volumes.

TABLE E-1 . (Continued)

|  |  | Highest concentration event[*] |  |  | Mean concentrations[*,#] |  |  | Number of events[*] |  |
|---|---|---|---|---|---|---|---|---|---|
| Year | Plot[δ] | Concen- tration, mg/l | Date | Volume, cm | Arith., mg/l | Std. dev., mg/l | Flow- wt., mg/l | With conc. | Total |
| 1976 | 1 | - | - | - | - | - | - | 0 | 0 |
|  | 2 | 11 | 10/20 | 0.10 | 11.4 | 0 | 11.4 | 1 | 1 |
|  | 3 | - | - | - | - | - | - | 0 | 0 |
|  | 4 | - | - | - | - | - | - | 0 | 0 |
|  | 5 | - | - | - | - | - | - | 0 | 0 |
|  | 6 | - | - | - | - | - | - | 0 | 0 |
|  | 7 | 48 | 9/15 | 0.09 | 6.4 | 12.1 | 3.1 | 13 | 13 |
|  | 8 | 4 | 12/12 | 2.00 | 2.5 | 0.9 | 2.7 | 10 | 10 |
|  | 9 | 5 | 12/16 | 0.46 | 2.9 | 0.9 | 2.9 | 8 | 8 |
|  | 10 | 2 | 1/28 | 0.13 | 1.4 | 0.4 | 1.4 | 9 | 9 |
|  | 11 | 3 | 1/28 | 0.06 | 1.4 | 1.1 | 1.0 | 4 | 4 |
|  | 12 | 4 | 1/28 | 0.12 | 1.6 | 1.3 | 0.9 | 5 | 5 |
|  | 13 | 8 | 9/27 | 0.11 | 2.7 | 2.6 | 1.7 | 5 | 5 |
|  | 100 | 3 | 1/28 | 0.08 | 2.0 | 0.7 | 1.5 | 5 | 5 |
|  | 110 | 17 | 7/25 | 0.06 | 5.0 | 5.6 | 1.9 | 6 | 6 |
|  | 120 | 6 | 1/27 | 0.10 | 2.9 | 2.1 | 2.1 | 4 | 4 |
|  | 130 | 2 | 2/2 | 1.45 | 2.2 | 0 | 2.2 | 1 | 1 |
| 1977 | 1 | 5 | 4/25 | 0.06 | 5.1 | 0 | 5.1 | 1 | 1 |
|  | 2 | - | - | - | - | - | - | 0 | 0 |
|  | 3 | - | - | - | - | - | - | 0 | 0 |
|  | 4 | 16 | 8/2 | 0.20 | 10.2 | 4.5 | 8.8 | 4 | 4 |
|  | 5 | 22 | 8/16 | 0.39 | 17.2 | 4.4 | 20.1 | 2 | 2 |
|  | 6 | 6 | 8/16 | 0.18 | 3.2 | 1.9 | 2.6 | 3 | 3 |
|  | 7 | 18 | 8/2 | 0.32 | 5.5 | 4.9 | 4.0 | 9 | 9 |
|  | 8 | 7 | 11/7 | 0.99 | 4.0 | 1.7 | 3.0 | 11 | 11 |
|  | 9 | 6 | 9/9 | 0.17 | 3.7 | 1.3 | 3.3 | 7 | 8 |
|  | 10 | 15 | 4/25 | 0.08 | 3.5 | 4.0 | 2.2 | 10 | 10 |
|  | 11 | 5 | 8/16 | 0.17 | 2.1 | 1.4 | 2.0 | 7 | 7 |
|  | 12 | 7 | 8/16 | 0.16 | 2.7 | 1.7 | 2.4 | 10 | 10 |
|  | 13 | 6 | 8/16 | 0.26 | 2.7 | 1.4 | 2.1 | 7 | 8 |
|  | 100 | 4 | 8/16 | 0.59 | 2.2 | 0.8 | 2.2 | 7 | 7 |
|  | 110 | 15 | 4/25 | 0.14 | 3.9 | 4.1 | 3.2 | 9 | 9 |
|  | 120 | 11 | 4/25 | 0.12 | 3.7 | 3.0 | 2.6 | 10 | 10 |
|  | 130 | 11 | 4/25 | 0.07 | 4.0 | 3.2 | 2.3 | 6 | 6 |
| 1978 | 1 | 10 | 6/7 | 0.27 | 7.8 | 1.9 | 8.1 | 5 | 5 |
|  | 2 | 4 | 1/20 | 0.49 | 3.3 | 0.9 | 3.8 | 4 | 4 |
|  | 3 | 4 | 1/20 | 0.73 | 3.0 | 0.9 | 3.4 | 3 | 3 |
|  | 4 | 6 | 7/16 | 0.07 | 4.7 | 0.7 | 4.6 | 3 | 3 |
|  | 5 | 10 | 7/16 | 0.06 | 9.8 | 0 | 9.7 | 1 | 1 |
|  | 6 | 14 | 7/16 | 0.06 | 5.7 | 5.2 | 3.9 | 4 | 4 |
|  | 7 | 20 | 5/15 | 1.15 | 5.1 | 4.6 | 4.6 | 13 | 13 |
|  | 8 | 6 | 5/15 | 0.42 | 3.0 | 1.2 | 2.7 | 13 | 13 |
|  | 9 | 13 | 5/9 | 0.21 | 3.9 | 3.5 | 2.7 | 12 | 12 |
|  | 10 | 13 | 7/11 | 0.08 | 2.9 | 3.0 | 1.7 | 19 | 19 |
|  | 11 | 21 | 7/11 | 0.19 | 3.3 | 4.9 | 2.0 | 14 | 14 |
|  | 12 | 10 | 7/11 | 0.13 | 2.1 | 2.2 | 1.7 | 15 | 15 |
|  | 13 | 31 | 7/11 | 0.13 | 6.0 | 9.8 | 3.9 | 11 | 11 |
|  | 100 | 18 | 7/11 | 0.27 | 3.2 | 4.0 | 2.0 | 15 | 15 |
|  | 110 | 34 | 7/11 | 0.40 | 4.4 | 7.5 | 3.8 | 17 | 17 |
|  | 120 | 19 | 7/11 | 0.59 | 3.9 | 4.6 | 3.3 | 16 | 16 |
|  | 130 | 32 | 7/11 | 0.26 | 6.4 | 8.5 | 4.5 | 10 | 10 |

TABLE E-2. RAINFALL RUNOFF CONCENTRATIONS - $NO_3$-N

| Year | Plot[δ] | Highest concentration event[*] |  |  | Mean concentrations[*,#] |  |  | Number of events |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Concentration, mg/l | Date | Volume, cm | Arith., mg/l | Std. dev., mg/l | Flow-wt., mg/l | With conc. | Total |
| 1973 | 1 | 8 | 6/18 | 0.08 | 2.4 | 2.6 | 1.1 | 7 | 11 |
|  | 2 | 10 | 11/28 | 0.16 | 2.8 | 2.9 | 1.6 | 7 | 11 |
|  | 3 | 3 | 7/16 | 0.46 | 2.2 | 0.5 | 1.9 | 3 | 7 |
|  | 4 | 54 | 11/28 | 0.10 | 15.3 | 22.4 | 3.3 | 4 | 8 |
|  | 5 | 14 | 11/28 | 0.08 | 6.5 | 4.5 | 2.7 | 6 | 10 |
|  | 6 | 13 | 7/27 | 0.09 | 7.9 | 4.8 | 6.7 | 3 | 6 |
|  | 7 | 3 | 7/27 | 0.80 | 1.8 | 0.6 | 1.7 | 4 | 9 |
|  | 8 | 3 | 6/18 | 0.20 | 1.2 | 0.8 | 0.9 | 6 | 9 |
|  | 9 | 2 | 6/18 | 0.20 | 1.2 | 0.6 | 1.0 | 6 | 9 |
| 1974 | 1 | 100 | 11/20 | 0.77 | 51.9 | 48.1 | 92.0 | 2 | 7 |
|  | 2 | 9 | 11/20 | 0.26 | 5.3 | 3.8 | 7.4 | 2 | 11 |
|  | 3 | - | - | - | - | - | - | 0 | 5 |
|  | 4 | 12 | 11/20 | 0.55 | 11.9 | 0 | 11.8 | 1 | 9 |
|  | 5 | 29 | 11/20 | 0.34 | 15.6 | 13.4 | 24.4 | 2 | 8 |
|  | 6 | 0 | 11/20 | 0.09 | 0.1 | 0 | 0.1 | 1 | 5 |
|  | 7 | 19 | 11/20 | 1.17 | 7.1 | 8.3 | 5.4 | 3 | 10 |
|  | 8 | 16 | 11/20 | 0.14 | 9.0 | 7.5 | 2.5 | 2 | 11 |
|  | 9 | 3 | 2/8 | 1.00 | 1.4 | 1.4 | 1.1 | 2 | 8 |
|  | 10 | 17 | 11/20 | 0.22 | 16.7 | 0 | 16.6 | 1 | 1 |
|  | 11 | 4 | 11/20 | 0.19 | 4.0 | 0 | 4.0 | 1 | 1 |
|  | 12 | 8 | 11/20 | 0.22 | 8.3 | 0 | 8.2 | 1 | 1 |
|  | 13 | 9 | 11/20 | 0.17 | 8.9 | 0 | 8.9 | 1 | 1 |
| 1975 | 1 | 16 | 7/25 | 0.29 | 5.3 | 6.2 | 3.7 | 7 | 7 |
|  | 2 | 7 | 9/1 | 0.16 | 1.9 | 2.0 | 1.3 | 7 | 7 |
|  | 3 | 8 | 9/1 | 0.10 | 2.6 | 3.2 | 1.0 | 4 | 4 |
|  | 4 | 39 | 9/1 | 0.53 | 10.8 | 13.4 | 9.6 | 8 | 8 |
|  | 5 | 7 | 9/1 | 0.13 | 2.2 | 2.3 | 1.3 | 7 | 7 |
|  | 6 | 8 | 9/1 | 0.16 | 2.9 | 2.9 | 1.8 | 8 | 8 |
|  | 7 | 47 | 7/25 | 0.81 | 7.8 | 11.8 | 6.5 | 16 | 16 |
|  | 8 | 9 | 7/25 | 0.81 | 2.1 | 2.3 | 2.1 | 14 | 15 |
|  | 9 | 21 | 9/1 | 0.16 | 3.9 | 5.7 | 3.7 | 13 | 13 |
|  | 10 | 2 | 7/15 | 0.81 | 0.9 | 0.7 | 0.8 | 11 | 11 |
|  | 11 | 6 | 9/1 | 0.08 | 1.8 | 1.7 | 1.2 | 9 | 9 |
|  | 12 | 2 | 7/16 | 0.81 | 1.0 | 0.7 | 0.9 | 10 | 12 |
|  | 13 | 2 | 7/15 | 0.60 | 1.4 | 0.7 | 1.3 | 6 | 8 |
|  | 100 | - | - | - | - | - | - | - | - |
|  | 110 | - | - | - | - | - | - | - | - |
|  | 120 | 1 | 11/13 | 0.08 | 0.5 | 0 | 0.4 | 1 | 1 |
|  | 130 | - | - | - | - | - | - | - | - |

(Continued)

*,δ,# - See footnotes for Table E-1.

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TABLE E-2. (Continued)

| Year | Plot$^{\delta}$ | Highest concentration event* | | | Mean concentrations*,# | | | Number of events* | |
|---|---|---|---|---|---|---|---|---|---|
| | | Concentration, mg/1 | Date | Volume, cm | Arith., mg/1 | Std. dev., mg/1 | Flow-wt., mg/1 | With conc. | Total |
| 1976 | 1 | - | - | - | - | - | - | 0 | 0 |
| | 2 | 9 | 10/20 | 0.10 | 8.8 | 0 | 8.8 | 1 | 1 |
| | 3 | - | - | - | - | - | - | 0 | 0 |
| | 4 | - | - | - | - | - | - | 0 | 0 |
| | 5 | - | - | - | - | - | - | 0 | 0 |
| | 6 | - | - | - | - | - | - | 0 | 0 |
| | 7 | 52 | 12/8 | 0.10 | 6.9 | 13.8 | 2.5 | 12 | 13 |
| | 8 | 7 | 12/20 | 0.11 | 2.5 | 2.7 | 2.0 | 10 | 10 |
| | 9 | 10 | 12/16 | 0.46 | 3.4 | 3.4 | 3.4 | 8 | 8 |
| | 10 | 2 | 1/28 | 0.13 | 0.8 | 0.5 | 0.6 | 7 | 9 |
| | 11 | 2 | 1/28 | 0.06 | 0.7 | 0.7 | 0.4 | 4 | 4 |
| | 12 | 2 | 1/28 | 0.12 | 1.0 | 0.8 | 0.7 | 4 | 5 |
| | 13 | 1 | 2/2 | 1.40 | 0.6 | 0.2 | 0.7 | 3 | 5 |
| | 100 | 1 | 1/27 | 0.50 | 0.4 | 0.1 | 0.3 | 5 | 5 |
| | 110 | 1 | 1/27 | 0.14 | 0.4 | 0.2 | 0.3 | 5 | 6 |
| | 120 | 1 | 1/27 | 0.10 | 0.2 | 0.2 | 0.1 | 3 | 4 |
| | 130 | 1 | 2/2 | 1.45 | 0.7 | 0 | 0.7 | 1 | 1 |
| 1977 | 1 | 2 | 4/25 | 0.06 | 2.3 | 0 | 2.3 | 1 | 1 |
| | 2 | - | - | - | - | - | - | 0 | 0 |
| | 3 | - | - | - | - | - | - | 0 | 0 |
| | 4 | 14 | 10/26 | 0.12 | 6.0 | 4.8 | 4.2 | 4 | 4 |
| | 5 | 6 | 10/26 | 0.08 | 3.8 | 1.9 | 2.5 | 2 | 2 |
| | 6 | 4 | 1/10 | 0.07 | 1.6 | 1.7 | 0.8 | 3 | 3 |
| | 7 | 9 | 8/2 | 0.32 | 2.7 | 2.4 | 1.7 | 9 | 9 |
| | 8 | 4 | 9/9 | 0.17 | 2.2 | 1.2 | 1.5 | 11 | 11 |
| | 9 | 12 | 9/9 | 0.17 | 3.5 | 3.6 | 1.9 | 7 | 8 |
| | 10 | 13 | 4/25 | 0.08 | 1.6 | 3.7 | 0.4 | 10 | 10 |
| | 11 | 1 | 3/22 | 0.55 | 0.5 | 0.3 | 0.4 | 7 | 7 |
| | 12 | 2 | 3/22 | 0.25 | 0.7 | 0.4 | 0.5 | 10 | 10 |
| | 13 | 1 | 3/13 | 0.45 | 0.3 | 0.2 | 0.2 | 7 | 8 |
| | 100 | 1 | 8/16 | 0.59 | 0.2 | 0.1 | 0.2 | 7 | 7 |
| | 110 | 14 | 4/25 | 0.14 | 1.7 | 4.4 | 0.6 | 9 | 9 |
| | 120 | 15 | 4/25 | 0.12 | 1.7 | 4.5 | 0.4 | 10 | 10 |
| | 130 | 11 | 4/25 | 0.08 | 2.0 | 4.3 | 0.4 | 6 | 6 |
| 1978 | 1 | 14 | 6/7 | 0.27 | 7.0 | 3.6 | 6.2 | 5 | 5 |
| | 2 | 4 | 1/26 | 0.06 | 2.9 | 1.5 | 2.9 | 4 | 4 |
| | 3 | 4 | 1/26 | 0.13 | 3.2 | 0.5 | 2.8 | 3 | 3 |
| | 4 | 6 | 7/16 | 0.07 | 3.0 | 2.4 | 2.5 | 3 | 3 |
| | 5 | 13 | 7/16 | 0.06 | 13.1 | 0 | 13.0 | 1 | 1 |
| | 6 | 1 | 7/16 | 0.06 | 0.5 | 0.4 | 0.4 | 4 | 4 |
| | 7 | 12 | 5/15 | 1.15 | 4.4 | 3.3 | 3.5 | 13 | 13 |
| | 8 | 8 | 5/9 | 0.38 | 2.9 | 1.9 | 2.4 | 13 | 13 |
| | 9 | 19 | 5/9 | 0.21 | 4.7 | 4.8 | 2.6 | 12 | 12 |
| | 10 | 10 | 7/11 | 0.08 | 1.8 | 2.6 | 0.7 | 19 | 19 |
| | 11 | 20 | 7/11 | 0.19 | 3.1 | 5.3 | 1.6 | 14 | 14 |
| | 12 | 7 | 7/11 | 0.13 | 1.5 | 1.8 | 0.7 | 15 | 15 |
| | 13 | 31 | 7/11 | 0.13 | 3.2 | 8.8 | 0.8 | 11 | 11 |
| | 100 | 14 | 7/11 | 0.27 | 1.5 | 3.6 | 0.6 | 13 | 15 |
| | 110 | 33 | 7/11 | 0.40 | 3.1 | 7.6 | 2.4 | 17 | 17 |
| | 120 | 15 | 7/11 | 0.59 | 1.3 | 3.8 | 1.4 | 15 | 16 |
| | 130 | 26 | 7/11 | 0.26 | 3.2 | 7.6 | 1.8 | 10 | 10 |

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## TABLE E-3. RAINFALL RUNOFF CONCENTRATIONS - COD

| | | Highest concentration event* | | | Mean concentrations*,# | | | Number of events* | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Plot[δ] | Concentration, mg/l | Date | Volume, cm | Arith., mg/l | Std. dev., mg/l | Flow-wt., mg/l | With conc. | Total |
| 1973 | 1 | 175 | 6/18 | 0.08 | 80 | 49 | 54 | 7 | 11 |
| | 2 | 115 | 5/22 | 0.82 | 62 | 34 | 54 | 8 | 11 |
| | 3 | 70 | 5/29 | 1.04 | 40 | 15 | 41 | 5 | 7 |
| | 4 | 105 | 11/28 | 0.10 | 48 | 27 | 36 | 6 | 8 |
| | 5 | 95 | 12/9 | 0.06 | 64 | 24 | 52 | 8 | 10 |
| | 6 | 325 | 7/27 | 0.09 | 134 | 95 | 127 | 5 | 6 |
| | 7 | 110 | 5/22 | 1.16 | 56 | 36 | 44 | 6 | 9 |
| | 8 | 150 | 5/29 | 1.71 | 80 | 47 | 70 | 7 | 9 |
| | 9 | 115 | 5/22 | 0.83 | 66 | 39 | 56 | 6 | 9 |
| 1974 | 1 | 330 | 9/3 | 0.45 | 156 | 145 | 122 | 6 | 7 |
| | 2 | 330 | 5/23 | 0.06 | 117 | 83 | 72 | 6 | 11 |
| | 3 | 415 | 9/3 | 0.13 | 146 | 52 | 39 | 3 | 5 |
| | 4 | 270 | 9/3 | 0.65 | 99 | 90 | 84 | 5 | 9 |
| | 5 | 90 | 11/20 | 0.34 | 50 | 26 | 43 | 5 | 8 |
| | 6 | 55 | 11/20 | 0.09 | 30 | 16 | 29 | 3 | 5 |
| | 7 | 275 | 9/3 | 0.65 | 100 | 85 | 76 | 7 | 10 |
| | 8 | 180 | 11/20 | 0.14 | 63 | 53 | 42 | 8 | 11 |
| | 9 | 365 | 9/3 | 2.06 | 115 | 58 | 133 | 5 | 8 |
| | 10 | 45 | 11/20 | 0.22 | 45 | 0 | 45 | 1 | 1 |
| | 11 | 35 | 11/20 | 0.19 | 35 | 0 | 35 | 1 | 1 |
| | 12 | 65 | 11/20 | 0.22 | 65 | 0 | 65 | 1 | 1 |
| | 13 | 40 | 11/20 | 0.17 | 40 | 0 | 40 | 1 | 1 |
| 1975 | 1 | 290 | 9/1 | 0.26 | 121 | 117 | 89 | 4 | 6 |
| | 2 | 95 | 9/22 | 0.11 | 53 | 28 | 40 | 5 | 7 |
| | 3 | 80 | 9/1 | 0.10 | 62 | 19 | 52 | 2 | 4 |
| | 4 | 240 | 9/1 | 0.53 | 82 | 73 | 88 | 6 | 8 |
| | 5 | 80 | 9/22 | 0.07 | 55 | 25 | 39 | 4 | 6 |
| | 6 | 125 | 9/1 | 0.16 | 59 | 42 | 41 | 5 | 8 |
| | 7 | 310 | 7/19 | 0.06 | 102 | 94 | 75 | 13 | 16 |
| | 8 | 90 | 7/25 | 0.81 | 54 | 19 | 50 | 13 | 15 |
| | 9 | 130 | 9/1 | 0.16 | 60 | 33 | 62 | 10 | 13 |
| | 10 | 40 | 9/1 | 0.16 | 30 | 8 | 28 | 8 | 11 |
| | 11 | 55 | 9/1 | 0.08 | 32 | 12 | 26 | 6 | 9 |
| | 12 | 70 | 9/1 | 0.10 | 40 | 17 | 28 | 7 | 12 |
| | 13 | 65 | 9/1 | 0.06 | 36 | 20 | 22 | 5 | 8 |
| | 100 | - | - | - | - | - | - | 0 | 0 |
| | 110 | - | - | - | - | - | - | 0 | 0 |
| | 120 | 95 | 11/13 | 0.08 | 95 | 0 | 95 | 1 | 1 |
| | 130 | - | - | - | - | - | - | 0 | 0 |

(Continued)

δ,*,# - See footnotes to Table E-1.

TABLE E-3. (Continued)

| | | Highest concentration event* | | | Mean concentrations*,# | | | Number of events* | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Plot§ | Concentration, mg/l | Date | Volume, cm | Arith., mg/l | Std. dev., mg/l | Flow-wt., mg/l | With conc. | Total |
| 1976 | 1 | - | - | - | - | - | - | 0 | 0 |
| | 2 | 25 | 10/20 | 0.10 | 25 | 0 | 25 | 1 | 1 |
| | 3 | 145 | 1/27 | 0.09 | 145 | 0 | 145 | 1 | 1 |
| | 4 | - | - | - | - | - | - | 0 | 0 |
| | 5 | - | - | - | - | - | - | 0 | 0 |
| | 6 | - | - | - | - | - | - | 0 | 0 |
| | 7 | 445 | 9/15 | 0.09 | 91 | 68 | 66 | 13 | 13 |
| | 8 | 60 | 12/13 | 0.58 | 42 | 15 | 35 | 10 | 10 |
| | 9 | 165 | 12/16 | 0.46 | 78 | 40 | 70 | 8 | 8 |
| | 10 | 80 | 12/12 | 1.23 | 31 | 23 | 38 | 9 | 9 |
| | 11 | 85 | 12/12 | 1.20 | 3[illegible] | 29 | 46 | 4 | 4 |
| | 12 | 25 | 12/16 | 0.21 | 17 | 6 | 15 | 5 | 5 |
| | 13 | 75 | 10/9 | 0.06 | 36 | 22 | 16 | 5 | 5 |
| | 100 | 50 | 12/12 | 2.00 | 41 | 11 | 39 | 5 | 5 |
| | 110 | 165 | 7/ 25 | 0.06 | 85 | 40 | 55 | 6 | 6 |
| | 120 | 175 | 1/27 | 0.10 | 75 | 58 | 57 | 4 | 4 |
| | 130 | 30 | 2/2 | 1.45 | 30 | 0 | 30 | 1 | 1 |
| 1977 | 1 | 85 | 4/25 | 0.06 | 85 | 0 | 85 | 1 | 1 |
| | 2 | - | - | - | - | - | - | 0 | 0 |
| | 3 | - | - | - | - | - | - | 0 | 0 |
| | 4 | 70 | 8/2 | 0.20 | 56 | 12 | 56 | 4 | 4 |
| | 5 | 105 | 8/16 | 0.39 | 70 | 34 | 92 | 2 | 2 |
| | 6 | 65 | 1/10 | 0.07 | 39 | 17 | 31 | 3 | 3 |
| | 7 | 120 | 3/7 | 1.25 | 69 | 34 | 59 | 9 | 9 |
| | 8 | 80 | 9/9 | 0.17 | 54 | 21 | 51 | 11 | 11 |
| | 9 | 75 | 9/9 | 0.17 | 49 | 15 | 44 | 7 | 8 |
| | 10 | 110 | 4/25 | 0.08 | 40 | 31 | 28 | 10 | 10 |
| | 11 | 55 | 3/22 | 0.55 | 33 | 11 | 31 | 7 | 7 |
| | 12 | 50 | 8/2 | 0.06 | 27 | 13 | 22 | 10 | 10 |
| | 13 | 60 | 8/2 | 0.08 | 32 | 15 | 27 | 7 | 8 |
| | 100 | 60 | 3/22 | 0.06 | 34 | 15 | 31 | 7 | 7 |
| | 110 | 110 | 4/25 | 0.14 | 55 | 28 | 43 | 9 | 9 |
| | 120 | 115 | 4/25 | 0.12 | 47 | 33 | 31 | 10 | 10 |
| | 130 | 110 | 4/25 | 0.07 | 50 | 30 | 38 | 6 | 6 |
| 1978 | 1 | 90 | 1/20 | 1.51 | 65 | 14 | 80 | 5 | 5 |
| | 2 | 70 | 1/26 | 0.06 | 54 | 25 | 56 | 4 | 4 |
| | 3 | 65 | 1/26 | 0.13 | 60 | 8 | 53 | 3 | 3 |
| | 4 | 80 | 1/20 | 0.12 | 58 | 20 | 62 | 3 | 3 |
| | 5 | 50 | 7/16 | 0.06 | 50 | 0 | 50 | 1 | 1 |
| | 6 | 45 | 1/20 | 0.11 | 31 | 12 | 26 | 4 | 4 |
| | 7 | 125 | 5/15 | 1.15 | 49 | 26 | 46 | 13 | 13 |
| | 8 | 65 | 5/9 | 0.38 | 39 | 12 | 37 | 13 | 13 |
| | 9 | 60 | 1/26 | 1.20 | 44 | 11 | 41 | 12 | 12 |
| | 10 | 115 | 9/11 | 0.07 | 36 | 26 | 25 | 19 | 19 |
| | 11 | 125 | 7/11 | 0.19 | 40 | 33 | 32 | 14 | 14 |
| | 12 | 65 | 7/11 | 0.13 | 28 | 18 | 35 | 15 | 15 |
| | 13 | 95 | 7/11 | 0.13 | 37 | 22 | 32 | 11 | 11 |
| | 100 | 105 | 7/11 | 0.27 | 42 | 23 | 33 | 15 | 15 |
| | 110 | 130 | 7/11 | 0.40 | 51 | 34 | 43 | 17 | 17 |
| | 120 | 110 | 7/11 | 0.59 | 49 | 32 | 42 | 16 | 16 |
| | 130 | 140 | 10/1 | 0.06 | 66 | 40 | 43 | 10 | 10 |

## TABLE E-4. RAINFALL RUNOFF CONCENTRATIONS - TOC

| | | Highest concentration event[*] | | | Mean concentrations[*,#] | | | Number of events[*] | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Plot[δ] | Concentration, mg/l | Date | Volume, cm | Arith., mg/l | Std. dev., mg/l | Flow-wt., mg/l | With conc. | Total |
| 1973 | 1 | 40 | 7/27 | 0.90 | 23 | 13 | 17 | 4 | 11 |
| | 2 | 32 | 7/27 | 0.59 | 22 | 10 | 14 | 4 | 11 |
| | 3 | 16 | 7/27 | 0.31 | 10 | 4 | 7 | 3 | 7 |
| | 4 | 45 | 11/28 | 0.10 | 18 | 16 | 9 | 4 | 8 |
| | 5 | 32 | 6/18 | 0.11 | 23 | 10 | 11 | 5 | 10 |
| | 6 | 57 | 7/27 | 0.09 | 26 | 22 | 22 | 3 | 6 |
| | 7 | 17 | 7/27 | 0.80 | 11 | 5 | 10 | 3 | 9 |
| | 8 | 25 | 6/18 | 0.20 | 13 | 8 | 9 | 4 | 9 |
| | 9 | 25 | 6/18 | 0.20 | 14 | 7 | 9 | 4 | 9 |
| 1974 | 1 | 35 | 2/8 | 0.07 | 35 | 0 | 35 | 1 | 7 |
| | 2 | 90 | 5/23 | 0.06 | 48 | 30 | 44 | 3 | 11 |
| | 3 | - | - | - | - | - | - | 0 | 5 |
| | 4 | - | - | - | - | - | - | 0 | 9 |
| | 5 | 30 | 6/3 | 0.08 | 25 | 5 | 25 | 2 | 8 |
| | 6 | - | - | - | - | - | - | 0 | 5 |
| | 7 | 30 | 2/8 | 1.94 | 25 | 4 | 25 | 3 | 10 |
| | 8 | 30 | 2/16 | 2.05 | 24 | 5 | 24 | 3 | 11 |
| | 9 | 25 | 2/8 | 1.00 | 25 | 1 | 25 | 3 | 8 |
| 1975[+] | 7 | 25 | 12/26 | 0.34 | 25 | 0 | 25 | 1 | 16 |
| | 8 | 20 | 12/31 | 0.13 | 20 | 0 | 20 | 1 | 15 |
| 1976 | 1 | - | - | - | - | - | - | 0 | 0 |
| | 2 | 45 | 10/20 | 0.10 | 45 | 0 | 45 | 1 | 1 |
| | 3 | - | - | - | - | - | - | 0 | 0 |
| | 4 | - | - | - | - | - | - | 0 | 0 |
| | 5 | - | - | - | - | - | - | 0 | 0 |
| | 6 | - | - | - | - | - | - | 0 | 0 |
| | 7 | 170 | 9/15 | 0.09 | 34 | 40 | 22 | 13 | 13 |
| | 8 | 45 | 12/20 | 0.11 | 19 | 14 | 12 | 10 | 10 |
| | 9 | 45 | 1/1 | 0.10 | 23 | 12 | 21 | 8 | 8 |
| | 10 | 25 | 12/12 | 1.23 | 9 | 7 | 13 | 8 | 9 |
| | 11 | 20 | 12/12 | 1.20 | 10 | 6 | 13 | 4 | 4 |
| | 12 | 8 | 9/27 | 0.07 | 6 | 2 | 6 | 5 | 5 |
| | 13 | 16 | 12/13 | 0.15 | 12 | 4 | 7 | 4 | 5 |
| | 100 | 25 | 12/12 | 2.00 | 13 | 8 | 15 | 5 | 5 |
| | 110 | 95 | 7/25 | 0.06 | 34 | 30 | 21 | 6 | 6 |
| | 120 | 25 | 12/7 | 0.06 | 22 | 4 | 24 | 3 | 4 |
| | 130 | 8 | 2/2 | 1.45 | 8 | 0 | 8 | 1 | 1 |

(Continued)

δ,*,# - See footnotes to Table E-1.

[+] Plots 1-13 had several runoff events but only plots 7 and 8 had any concentration data.

TABLE E-4. (continued)

| Year | Plot[δ] | Highest concentration event[*] |  |  | Mean concentrations[*,#] |  |  | Number of events[*] |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Concentration, mg/l | Date | Volume, cm | Arith., mg/l | Std. dev., mg/l | Flow-wt., mg/l | With conc. | Total |
| 1977 | 1 | 14 | 4/25 | 0.06 | 14 | 0 | 14 | 1 | 1 |
|  | 2 | - | - | - | - | - | - | 0 | 0 |
|  | 3 | - | - | - | - | - | - | 0 | 0 |
|  | 4 | 31 | 8/2 | 0.20 | 23 | 8 | 22 | 4 | 4 |
|  | 5 | 28 | 8/16 | 0.39 | 22 | 6 | 26 | 2 | 2 |
|  | 6 | 40 | 1/10 | 0.07 | 25 | 15 | 18 | 2 | 3 |
|  | 7 | 29 | 8/2 | 0.32 | 18 | 7 | 15 | 9 | 9 |
|  | 8 | 29 | 9/9 | 0.17 | 15 | 6 | 13 | 11 | 11 |
|  | 9 | 28 | 9/9 | 0.17 | 17 | 8 | 16 | 7 | 8 |
|  | 10 | 20 | 4/25 | 0.08 | 10 | 5 | 9 | 10 | 10 |
|  | 11 | 12 | 1/10 | 1.98 | 9 | 3 | 9 | 7 | 7 |
|  | 12 | 11 | 8/16 | 0.16 | 8 | 3 | 9 | 10 | 10 |
|  | 13 | 12 | 11/7 | 1.18 | 8 | 3 | 9 | 7 | 8 |
|  | 100 | 17 | 11/7 | 1.87 | 10 | 3 | 10 | 7 | 7 |
|  | 110 | 21 | 4/25 | 0.14 | 13 | 4 | 12 | 9 | 9 |
|  | 120 | 21 | 4/25 | 0.12 | 11 | 6 | 9 | 10 | 10 |
|  | 130 | 21 | 4/25 | 0.07 | 14 | 5 | 12 | 6 | 6 |
| 1978 | 1 | 27 | 1/26 | 0.26 | 22 | 5 | 24 | 5 | 5 |
|  | 2 | 22 | 1/26 | 0.06 | 17 | 9 | 19 | 4 | 4 |
|  | 3 | 24 | 1/26 | 0.13 | 23 | 1 | 22 | 3 | 3 |
|  | 4 | 14 | 7/16 | 0.07 | 13 | 1 | 13 | 3 | 3 |
|  | 5 | 16 | 7/16 | 0.06 | 16 | 0 | 16 | 1 | 1 |
|  | 6 | 11 | 7/16 | 0.06 | 7 | 2 | 6 | 4 | 4 |
|  | 7 | 32 | 5/15 | 1.15 | 18 | 6 | 17 | 13 | 13 |
|  | 8 | 29 | 5/9 | 0.38 | 17 | 7 | 15 | 13 | 13 |
|  | 9 | 26 | 5/9 | 0.21 | 15 | 5 | 13 | 12 | 12 |
|  | 10 | 46 | 9/11 | 0.07 | 14 | 10 | 9 | 19 | 19 |
|  | 11 | 47 | 7/11 | 0.19 | 12 | 10 | 9 | 14 | 14 |
|  | 12 | 19 | 7/11 | 0.13 | 9 | 3 | 8 | 15 | 15 |
|  | 13 | 32 | 7/11 | 0.13 | 10 | 7 | 8 | 11 | 11 |
|  | 100 | 32 | 7/11 | 0.27 | 15 | 9 | 11 | 14 | 15 |
|  | 110 | 53 | 10/1 | 0.22 | 20 | 11 | 16 | 17 | 17 |
|  | 120 | 41 | 10/1 | 0.17 | 14 | 12 | 11 | 16 | 16 |
|  | 130 | 52 | 10/1 | 0.06 | 19 | 14 | 12 | 10 | 10 |

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## TABLE E-5. RAINFALL RUNOFF CONCENTRATIONS - P

| Year | Plot[δ] | Highest concentration event[*] |  |  | Mean concentrations[*,#] |  |  | Number of events |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Concentration, mg/l | Date | Volume, cm | Arith., mg/l | Std. dev., mg/l | Flow-wt., mg/l | With conc. | Total |
| 1973[+] | 1 | 9 | 7/16 | 1.24 | 4.7 | 3.2 | 4.2 | 4 | 11 |
|  | 2 | 3 | 7/16 | 0.34 | 1.4 | 1.1 | 1.1 | 5 | 11 |
|  | 3 | 6 | 7/16 | 0.45 | 2.9 | 2.8 | 2.0 | 3 | 7 |
|  | 4 | 8 | 7/16 | 0.76 | 3.9 | 2.8 | 3.6 | 4 | 8 |
|  | 5 | 8 | 7/16 | 0.17 | 3.2 | 2.9 | 1.7 | 5 | 10 |
|  | 6 | 2 | 5/29 | 0.33 | 1.3 | 1.0 | 1.2 | 3 | 6 |
|  | 7 | 8 | 7/16 | 1.49 | 3.5 | 4.0 | 3.2 | 3 | 9 |
|  | 8 | 3 | 5/29 | 1.71 | 2.3 | 1.3 | 1.4 | 4 | 9 |
|  | 9 | 3 | 7/16 | 0.96 | 2.1 | 1.2 | 1.6 | 4 | 9 |
| 1974 | 1 | 6 | 5/12 | 0.08 | 3.1 | 1.8 | 2.2 | 5 | 7 |
|  | 2 | 6 | 9/3 | 0.25 | 2.4 | 1.9 | 1.2 | 7 | 11 |
|  | 3 | 9 | 9/3 | 0.13 | 3.0 | 3.8 | 1.4 | 4 | 5 |
|  | 4 | 4 | 6/15 | 2.04 | 2.0 | 1.1 | 2.3 | 5 | 9 |
|  | 5 | 5 | 6/15 | 2.05 | 3.4 | 1.6 | 4.5 | 5 | 8 |
|  | 6 | 15 | 8/7 | 0.07 | 7.5 | 7.2 | 3.0 | 4 | 5 |
|  | 7 | 25 | 11/20 | 1.16 | 6.5 | 10.6 | 5.5 | 5 | 10 |
|  | 8 | 4 | 9/3 | 0.28 | 1.7 | 1.4 | 1.3 | 6 | 11 |
|  | 9 | 6 | 5/23 | 0.05 | 2.0 | 2.0 | 1.2 | 5 | 8 |
| 1975[#] | 1 | 16 | July | 1.17 | 10.0 | 8.6 | 8.8 | 3 | 7 |
|  | 2 | 7 | July | 0.86 | 2.2 | 3.0 | 3.0 | 5 | 7 |
|  | 3 | 8 | July | 0.40 | 4.8 | 3.8 | 2.6 | 3 | 4 |
|  | 4 | 19 | Sept. | 0.96 | 11.8 | 9.5 | 11.3 | 3 | 8 |
|  | 5 | 24 | June | 0.10 | 8.6 | 12.9 | 2.3 | 3 | 7 |
|  | 6 | 7 | Sept. | 0.26 | 3.1 | 2.8 | 2.5 | 4 | 8 |
|  | 7 | 15 | July | 3.24 | 5.6 | 5.7 | 7.5 | 5 | 16 |
|  | 8 | 2 | July | 2.74 | 1.3 | 0.9 | 1.4 | 5 | 15 |
|  | 9 | 3 | Sept. | 1.52 | 1.5 | 1.1 | 1.6 | 3 | 13 |
|  | 10 | 0.5 | Sept. | 0.52 | 0.30 | 0.11 | 0.32 | 4 | 11 |
|  | 11 | 0.5 | July | 2.24 | 0.37 | 0.15 | 0.35 | 3 | 9 |
|  | 12 | 0.4 | July | 2.18 | 0.22 | 0.09 | 0.28 | 4 | 12 |
|  | 13 | 0.3 | Sept. | 0.18 | 0.25 | 0.06 | 0.23 | 3 | 8 |

(Continued)

*,δ,# - See footnotes for Table E-1.

[+] Concentrations for 1973 are for orthophosphate phosphorus instead of total phosphorus.

[#] Concentrations for 1975 are taken from monthly flow-weighted mean concentration instead of individual event concentrations. "Number of events with concentration" are the number of months with monthly composite sample with concentration. "Number of events total" are the number of individual events with runoff $\geq$ 0.05 cm. The only months with monthly volume > 0.05 cm and without concentration data were: Jan., plot 4, 0.29 cm; July, plot 5, 0.87 cm; and July, plot 9, 2.65 cm.

TABLE E-5.  (continued)

| Year | Plot$^{\delta}$ | Highest concentration event$^{*}$ | | | Mean concentrations$^{*,\#}$ | | | Number of events$^{*}$ | |
|---|---|---|---|---|---|---|---|---|---|
| | | Concentration, mg/1 | Date | Volume, cm | Arith., mg/1 | Std. dev., mg/1 | Flow-wt., mg/1 | With conc. | Total |
| 1976 | 1 | - | - | - | - | - | - | 0 | 0 |
| | 2 | 4 | 10/20 | 0.10 | 3.8 | 0 | 3.8 | 1 | 1 |
| | 3 | - | - | - | - | - | - | 0 | 0 |
| | 4 | - | - | - | - | - | - | 0 | 0 |
| | 5 | - | - | - | - | - | - | 0 | 0 |
| | 6 | - | - | - | - | - | - | 0 | 0 |
| | 7 | 27 | 9/15 | 0.09 | 9.1 | 8.3 | 5.1 | 13 | 13 |
| | 8 | 4 | 12/16 | 0.31 | 1.6 | 1.1 | 1.6 | 10 | 10 |
| | 9 | 6 | 12/16 | 0.46 | 2.3 | 1.7 | 2.6 | 8 | 8 |
| | 10 | 0.3 | 1/27 | 0.09 | 0.2 | 0 | 0.2 | 9 | 9 |
| | 11 | 0.3 | 1/28 | 0.06 | 0.1 | 0 | 0.1 | 4 | 4 |
| | 12 | 0.2 | 9/27 | 0.07 | 0.1 | 0 | 0.1 | 5 | 5 |
| | 13 | 0.6 | 10/9 | 0.06 | 0.3 | 0.2 | 0.2 | 5 | 5 |
| | 100 | 0.3 | 12/7 | 0.14 | 0.2 | 0 | 0.1 | 5 | 5 |
| | 110 | 5.2 | 7/25 | 0.06 | 1.2 | 1.8 | 0.3 | 6 | 6 |
| | 120 | 0.7 | 1/27 | 0.10 | 0.4 | 0.2 | 0.3 | 4 | 4 |
| | 130 | 0.2 | 2/2 | 1.45 | 0.2 | 0 | 0.2 | 1 | 1 |
| 1977 | 1 | 6 | 4/25 | 0.06 | 5.7 | 0 | 5.7 | 1 | 1 |
| | 2 | - | - | - | - | - | - | 0 | 0 |
| | 3 | - | - | - | - | - | - | 0 | 0 |
| | 4 | 35 | 8/2 | 0.20 | 15.2 | 12.7 | 14.8 | 4 | 4 |
| | 5 | 12 | 8/16 | 0.39 | 7.4 | 5.1 | 10.7 | 2 | 2 |
| | 6 | 9 | 1/10 | 0.07 | 3.6 | 4.0 | 1.6 | 3 | 3 |
| | 7 | 38 | 8/2 | 0.32 | 10.8 | 11.2 | 6.7 | 9 | 9 |
| | 8 | 12 | 9/9 | 0.17 | 2.9 | 2.8 | 2.0 | 11 | 11 |
| | 9 | 21 | 11/7 | 1.71 | 6.1 | 6.6 | 5.9 | 7 | 8 |
| | 10 | 0.5 | 4/25 | 0.08 | 0.2 | 0.1 | 0.2 | 10 | 10 |
| | 11 | 0.3 | 8/16 | 0.17 | 0.2 | 0 | 0.2 | 7 | 7 |
| | 12 | 0.4 | 8/2 | 0.06 | 0.2 | 0 | 0.2 | 10 | 10 |
| | 13 | 0.4 | 8/2 | 0.08 | 0.3 | 0 | 0.2 | 7 | 8 |
| | 100 | 1.5 | 3/22 | 0.06 | 0.5 | 0.5 | 0.4 | 7 | 7 |
| | 110 | 1.2 | 3/13 | 0.25 | 0.5 | 0.3 | 0.4 | 9 | 9 |
| | 120 | 0.8 | 8/16 | 1.20 | 0.4 | 0.2 | 0.4 | 10 | 10 |
| | 130 | 1.2 | 8/16 | 0.27 | 0.5 | 0.3 | 0.3 | 6 | 6 |
| 1978 | 1 | 13 | 6/7 | 0.27 | 8.0 | 2.6 | 7.7 | 5 | 5 |
| | 2 | 3 | 1/20 | 0.49 | 2.3 | 0.6 | 2.9 | 4 | 4 |
| | 3 | 5 | 1/20 | 0.73 | 3.8 | 0.9 | 4.5 | 3 | 3 |
| | 4 | 3 | 7/16 | 0.07 | 2.7 | 0.5 | 2.5 | 3 | 3 |
| | 5 | 6 | 7/16 | 0.06 | 6.3 | 0 | 6.2 | 1 | 1 |
| | 6 | 14 | 7/16 | 0.06 | 3.8 | 5.9 | 1.9 | 4 | 4 |
| | 7 | 16 | 5/15 | 1.15 | 5.5 | 3.6 | 4.7 | 13 | 13 |
| | 8 | 5 | 5/15 | 0.42 | 1.9 | 1.2 | 1.5 | 13 | 13 |
| | 9 | 6 | 5/15 | 0.17 | 2.4 | 1.5 | 1.7 | 12 | 12 |
| | 10 | 1.3 | 3/10 | 2.00 | 0.4 | 0.3 | 0.4 | 19 | 19 |
| | 11 | 4.3 | 7/16 | 0.16 | 0.7 | 1.1 | 0.5 | 14 | 14 |
| | 12 | 0.8 | 7/11 | 0.13 | 0.2 | 0.2 | 0.3 | 15 | 15 |
| | 13 | 1.7 | 7/11 | 0.13 | 0.4 | 0.5 | 0.4 | 11 | 11 |
| | 100 | 3.7 | 6/9 | 0.67 | 0.9 | 1.0 | 0.6 | 15 | 15 |
| | 110 | 3.1 | 3/10 | 0.67 | 0.9 | 1.0 | 0.7 | 17 | 17 |
| | 120 | 2.8 | 3/10 | 0.67 | 0.8 | 0.8 | 0.6 | 16 | 16 |
| | 130 | 3.3 | 7/11 | 0.26 | 1.3 | 1.1 | 0.8 | 10 | 10 |

### TABLE E-6. RAINFALL RUNOFF CONCENTRATIONS - $Cl^-$

| Year | Plot$^{\delta}$ | Highest concentration event$^{*}$ | | | Mean concentrations$^{*,\#}$ | | | Number of events | |
|---|---|---|---|---|---|---|---|---|---|
| | | Concentration, mg/l | Date | Volume, cm | Arith., mg/l | Std. dev., mg/l | Flow-wt., mg/l | With conc. | Total |
| 1973 | 1 | 29 | 6/18 | 0.08 | 12.6 | 11.3 | 5.4 | 3 | 11 |
| | 2 | 4 | 7/27 | 0.59 | 3.6 | 0 | 3.6 | 1 | 11 |
| | 3 | 2 | 5/29 | 1.04 | 1.5 | 0 | 1.5 | 2 | 7 |
| | 4 | 4 | 7/27 | 0.65 | 2.8 | 1.1 | 2.5 | 2 | 8 |
| | 5 | 10 | 7/27 | 0.07 | 5.2 | 3.2 | 3.4 | 3 | 10 |
| | 6 | 7 | 7/27 | 0.09 | 4.8 | 2.6 | 3.3 | 2 | 6 |
| | 7 | 4 | 5/29 | 1.83 | 2.1 | 1.5 | 2.7 | 2 | 9 |
| | 8 | 9 | 6/18 | 0.20 | 4.8 | 3.6 | 3.5 | 3 | 9 |
| | 9 | 12 | 6/18 | 0.20 | 7.9 | 4.3 | 4.5 | 2 | 9 |
| 1974 | 1 | 80 | 5/13 | 0.08 | 41 | 31 | 20 | 5 | 7 |
| | 2 | 63 | 5/13 | 0.18 | 27 | 19 | 15 | 7 | 11 |
| | 3 | 101 | 9/3 | 0.13 | 32 | 40 | 11 | 4 | 5 |
| | 4 | 49 | 9/3 | 0.65 | 23 | 14 | 18 | 6 | 9 |
| | 5 | 99 | 6/3 | 0.08 | 44 | 32 | 25 | 5 | 8 |
| | 6 | 23 | 6/15 | 1.80 | 19 | 4 | 22 | 4 | 5 |
| | 7 | 59 | 9/3 | 0.65 | 28 | 21 | 21 | 5 | 10 |
| | 8 | 28 | 9/3 | 0.28 | 15 | 7 | 13 | 6 | 11 |
| | 9 | 52 | 9/3 | 2.06 | 22 | 17 | 23 | 4 | 8 |
| | 10 | 8 | 11/20 | 0.22 | 8.3 | 0 | 8.3 | 1 | 1 |
| | 11 | 2 | 11/20 | 0.19 | 2.0 | 0 | 2.0 | 1 | 1 |
| | 12 | - | - | - | - | - | - | 0 | 1 |
| | 13 | - | - | - | - | - | - | 0 | 1 |
| 1975 | 1 | 33 | 9/1 | 0.26 | 12.6 | 13.9 | 10.4 | 4 | 6 |
| | 2 | 9 | 9/1 | 0.16 | 5.2 | 2.3 | 5.9 | 5 | 7 |
| | 3 | 19 | 9/1 | 0.10 | 13.3 | 5.5 | 10.2 | 2 | 4 |
| | 4 | 37 | 9/1 | 0.53 | 12.8 | 11.2 | 12.6 | 6 | 8 |
| | 5 | 16 | 9/1 | 0.14 | 6.2 | 6.7 | 2.6 | 4 | 6 |
| | 6 | 24 | 9/1 | 0.16 | 9.5 | 9.4 | 5.3 | 5 | 8 |
| | 7 | 65 | 7/19 | 0.06 | 13.2 | 18.3 | 8.2 | 13 | 16 |
| | 8 | 8 | 9/1 | 0.39 | 5.1 | 2.2 | 4.7 | 13 | 15 |
| | 9 | 26 | 9/1 | 0.16 | 6.6 | 6.9 | 5.3 | 10 | 13 |
| | 10 | 7 | 9/1 | 0.16 | 3.0 | 1.8 | 1.9 | 8 | 11 |
| | 11 | 8 | 7/17 | 0.62 | 4.2 | 2.3 | 3.6 | 6 | 9 |
| | 12 | 14 | 9/1 | 0.10 | 3.5 | 4.3 | 2.1 | 7 | 12 |
| | 13 | 3 | 7/17 | 0.23 | 1.6 | 1.1 | 1.3 | 4 | 8 |
| | 100 | - | - | - | - | - | - | 0 | 0 |
| | 110 | - | - | - | - | - | - | 0 | 0 |
| | 120 | 1 | 11/13 | 0.08 | 0.9 | 0 | 0.9 | 1 | 1 |
| | 130 | - | - | - | - | - | - | 0 | 0 |

(Continued)

*,δ,# - See footnotes for Table E-1

TABLE E-6. (Continued)

| Year | Plot$^{\delta}$ | Highest concentration event$^{*}$ |  |  | Mean concentrations$^{*,\#}$ |  |  | Number of events |  |
|---|---|---|---|---|---|---|---|---|---|
|  |  | Concentration, mg/l | Date | Volume, cm | Arith., mg/l | Std. dev., mg/l | Flow-wt., mg/l | With conc. | Total |
| 1976 | 1 | - | - | - | - | - | - | 0 | 0 |
|  | 2 | 11 | 10/20 | 0.10 | 10.6 | 0 | 10.6 | 1 | 1 |
|  | 3 | - | - | - | - | - | - | 0 | 0 |
|  | 4 | - | - | - | - | - | - | 0 | 0 |
|  | 5 | - | - | - | - | - | - | 0 | 0 |
|  | 6 | - | - | - | - | - | - | 0 | 0 |
|  | 7 | 7 | 10/20 | 0.13 | 2.8 | 1.8 | 2.1 | 12 | 13 |
|  | 8 | 7 | 1/1 | 0.33 | 3.2 | 1.8 | 2.7 | 10 | 10 |
|  | 9 | 5 | 12/13 | 0.58 | 3.2 | 1.4 | 2.8 | 8 | 8 |
|  | 10 | 5 | 2/2 | 1.06 | 2.7 | 1.1 | 2.9 | 7 | 9 |
|  | 11 | 3 | 1/28 | 0.06 | 2.7 | 0.7 | 2.5 | 4 | 4 |
|  | 12 | 4 | 12/16 | 0.21 | 2.8 | 0.7 | 2.4 | 4 | 5 |
|  | 13 | 3 | 2/2 | 1.40 | 2.6 | 0.2 | 2.8 | 3 | 5 |
|  | 100 | 2 | 1/28 | 0.08 | 1.4 | 0.3 | 1.3 | 5 | 5 |
|  | 110 | 52 | 7/25 | 0.06 | 11.6 | 19.8 | 2.0 | 5 | 6 |
|  | 120 | 4 | 1/27 | 0.10 | 1.7 | 1.3 | 1.0 | 3 | 4 |
|  | 130 | 1 | 2/2 | 1.45 | 1.2 | 0 | 1.2 | 1 | 1 |
| 1977 | 1 | 6 | 4/25 | 0.06 | 6.2 | 0 | 6.2 | 1 | 1 |
|  | 2 | - | - | - | - | - | - | 0 | 0 |
|  | 3 | - | - | - | - | - | - | 0 | 0 |
|  | 4 | 14 | 10/26 | 0.12 | 9.2 | 3.0 | 8.4 | 4 | 4 |
|  | 5 | 16 | 8/16 | 0.39 | 11.3 | 4.6 | 14.3 | 2 | 2 |
|  | 6 | 6 | 1/10 | 0.07 | 3.5 | 1.7 | 2.8 | 3 | 3 |
|  | 7 | 5 | 8/2 | 0.32 | 2.9 | 1.4 | 2.4 | 9 | 9 |
|  | 8 | 7 | 9/9 | 0.17 | 3.4 | 1.5 | 2.9 | 11 | 11 |
|  | 9 | 11 | 9/9 | 0.17 | 4.1 | 2.8 | 3.0 | 7 | 8 |
|  | 10 | 4 | 3/22 | 0.45 | 1.9 | 1.0 | 1.6 | 10 | 10 |
|  | 11 | 9 | 3/22 | 0.55 | 3.5 | 2.6 | 2.9 | 7 | 7 |
|  | 12 | 4 | 8/2 | 0.06 | 1.8 | 0.9 | 2.0 | 10 | 10 |
|  | 13 | 3 | 8/2 | 0.08 | 1.6 | 0.8 | 1.5 | 7 | 8 |
|  | 100 | 2 | 1/10 | 1.88 | 1.3 | 0.5 | 1.5 | 7 | 7 |
|  | 110 | 4 | 1/14 | 0.09 | 1.9 | 0.8 | 1.6 | 9 | 9 |
|  | 120 | 4 | 8/2 | 0.11 | 1.9 | 1.1 | 1.9 | 10 | 10 |
|  | 130 | 4 | 1/14 | 0.25 | 2.2 | 1.0 | 2.1 | 6 | 6 |
| 1978 | 1 | 5 | 1/20 | 1.51 | 3.9 | 1.1 | 4.7 | 5 | 5 |
|  | 2 | 2 | 1/26 | 0.06 | 1.8 | 0.5 | 1.7 | 4 | 4 |
|  | 3 | 2 | 1/26 | 0.13 | 2.0 | 0.1 | 1.9 | 3 | 3 |
|  | 4 | 5 | 7/16 | 0.07 | 2.6 | 1.4 | 2.3 | 3 | 3 |
|  | 5 | 11 | 7/16 | 0.06 | 11.1 | 0 | 11.0 | 1 | 1 |
|  | 6 | 6 | 7/16 | 0.06 | 2.4 | 2.4 | 1.6 | 4 | 4 |
|  | 7 | 20 | 5/15 | 1.15 | 3.3 | 5.0 | 2.8 | 13 | 13 |
|  | 8 | 8 | 5/15 | 0.42 | 2.1 | 1.9 | 1.7 | 13 | 13 |
|  | 9 | 14 | 5/9 | 0.21 | 3.7 | 3.9 | 2.0 | 12 | 12 |
|  | 10 | 10 | 9/3 | 0.10 | 2.3 | 2.5 | 1.3 | 19 | 19 |
|  | 11 | 8 | 3/13 | 0.12 | 2.8 | 1.7 | 2.5 | 14 | 14 |
|  | 12 | 2 | 5/8 | 0.15 | 1.3 | 0.3 | 1.3 | 14 | 15 |
|  | 13 | 4 | 7/11 | 0.13 | 1.4 | 0.9 | 1.2 | 11 | 11 |
|  | 100 | 4 | 7/11 | 0.27 | 1.4 | 0.8 | 1.2 | 15 | 15 |
|  | 110 | 16 | 3/13 | 0.48 | 3.8 | 4.5 | 3.0 | 16 | 16 |
|  | 120 | 17 | 9/3 | 0.12 | 2.8 | 4.0 | 1.8 | 16 | 16 |
|  | 130 | 18 | 10/1 | 0.06 | 4.2 | 5.1 | 1.9 | 10 | 10 |

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## TABLE E-7. RAINFALL RUNOFF CONCENTRATIONS - $NH_3$-N AND O-$PO_4$-P

| | | Highest concentration event* | | | Mean concentrations*,# | | | Number of events* | |
|---|---|---|---|---|---|---|---|---|---|
| Year | Plot$^\delta$ | Concentration., mg/l | Date | Volume, cm | Arith., mg/l | Std. dev., mg/l | Flow-wt., mg/l | With conc. | Total |
| | | | | $NH_3$-N | | | | | |
| 1978 | 1 | 9 | 6/7 | 0.27 | 8.9 | 0 | 8.9 | 1 | 5 |
| | 2 | 1 | 11/8 | 0.09 | 0.9 | 0 | 0.9 | 1 | 4 |
| | 3 | - | - | - | - | - | - | 0 | 3 |
| | 4 | 2 | 7/16 | 0.07 | 1.5 | 0 | 1.5 | 1 | 3 |
| | 5 | 4 | 7/16 | 0.06 | 4.2 | 0 | 4.2 | 1 | 1 |
| | 6 | 14 | 7/16 | 0.06 | 6.8 | 6.7 | 2.8 | 2 | 4 |
| | 7 | 14 | 5/15 | 1.15 | 3.9 | 4.9 | 4.0 | 6 | 13 |
| | 8 | 4 | 5/15 | 0.42 | 1.4 | 1.3 | 1.1 | 6 | 13 |
| | 9 | 10 | 5/9 | 0.21 | 3.6 | 3.6 | 1.4 | 5 | 12 |
| | 10+ | 10 | 7/11 | 0.08 | 2.1 | 2.8 | 1.1 | 9 | 19 |
| | 11+ | 19 | 7/11 | 0.19 | 3.9 | 6.7 | 2.7 | 6 | 14 |
| | 12+ | 7 | 7/11 | 0.13 | 1.6 | 2.3 | 0.9 | 6 | 15 |
| | 13+ | 28 | 7/11 | 0.13 | 6.1 | 10.9 | 2.5 | 5 | 11 |
| | 100+ | 13 | 7/11 | 0.27 | 3.0 | 4.0 | 2.9 | 8 | 15 |
| | 110+ | 28 | 7/11 | 0.40 | 4.3 | 8.6 | 6.7 | 9 | 17 |
| | 120+ | 14 | 7/11 | 0.59 | 3.3 | 4.4 | 4.8 | 8 | 16 |
| | 130+ | 22 | 7/11 | 0.26 | 5.0 | 7.9 | 7.5 | 6 | 10 |
| | | | | OP | | | | | |
| 1978 | 1 | 6.6 | 6/7 | 0.27 | 6.6 | 0 | 6.6 | 1 | 5 |
| | 2 | 1.9 | 11/8 | 0.09 | 1.9 | 0 | 1.9 | 1 | 4 |
| | 3 | - | - | - | - | - | - | 0 | 3 |
| | 4 | 3.2 | 7/16 | 0.07 | 3.2 | 0 | 3.2 | 1 | 3 |
| | 5 | 6.0 | 7/16 | 0.06 | 6.0 | 0 | 6.0 | 1 | 1 |
| | 6 | 13.7 | 7/16 | 0.06 | 6.9 | 6.8 | 2.7 | 2 | 4 |
| | 7 | 16.0 | 5/15 | 1.15 | 7.9 | 3.9 | 7.7 | 6 | 13 |
| | 8 | 5.1 | 5/15 | 0.42 | 2.4 | 1.3 | 2.2 | 6 | 13 |
| | 9 | 4.9 | 5/9 | 0.21 | 3.2 | 1.3 | 2.4 | 5 | 12 |
| | 10 | 0.8 | 9/3 | 0.10 | 0.3 | 0.2 | 0.3 | 9 | 19 |
| | 11 | 1.0 | 7/11 | 0.19 | 0.3 | 0.3 | 0.2 | 7 | 14 |
| | 12 | 0.3 | 7/11 | 0.13 | 0.2 | 0 | 0.1 | 5 | 15 |
| | 13 | 0.3 | 4/26 | 0.84 | 0.2 | 0 | 0.2 | 4 | 11 |
| | 100 | 1.1 | 5/8 | 0.11 | 0.6 | 0.3 | 0.5 | 8 | 15 |
| | 110 | 2.3 | 7/11 | 0.40 | 0.8 | 0.8 | 0.9 | 10 | 17 |
| | 120 | 2.7 | 9/3 | 0.12 | 0.8 | 0.8 | 0.6 | 9 | 16 |
| | 130 | 2.1 | 10/1 | 0.06 | 1.1 | 0.6 | 1.0 | 6 | 10 |

δ,*,# - See footnotes to Table E-1.

+All non-irrigated plots were topdressed with $NH_4NO_3$ on 7/6.

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## TABLE E-8. ANNUAL VOLUME-WEIGHTED MEAN CONCENTRATIONS OF METALS AND CATIONS IN RAIN RUNOFF*

| | Parameter Concentration, mg/l | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Na | | | | K | | | |
| Plot[+] | 1975 | 1976 | 1977 | 1978 | 1975 | 1976 | 1977 | 1978 |
| 1 | 9 | 80 | 52 | 11 | 14 | 191 | 45 | 5 |
| 4 | 12 | 33 | 14 | 19 | 17 | 43 | 9 | 8 |
| 7 | 7 | 4 | 6 | 7 | 12 | 12 | 6 | 1 |
| 3 | 5 | 9 | 29 | 11 | 6 | 6 | 38 | 5 |
| 5 | 5 | 38 | 27 | 16 | 8 | 48 | 13 | 9 |
| 9 | 5 | 3 | 7 | 8 | 6 | 14 | 4 | 5 |
| 2 | 3 | 14 | 9 | 6 | 4 | 25 | 1 | 2 |
| 6 | 5 | 122 | 6 | 5 | 5 | 272 | 15 | 5 |
| 8 | 3 | 4 | 4 | 5 | 6 | 10 | 6 | 1 |
| 10 | 1.2 | 1.4 | 2.4 | 2.2 | 1.2 | 2.4 | 2.1 | 1.5 |
| 12 | 1.4 | 2.1 | 3.2 | 2.8 | 0.9 | 2.4 | 2.2 | 1.3 |
| 100 | 4.6 | 1.4 | 3.6 | 4.2 | 2.2 | 3.4 | 2.9 | 1.7 |
| 120 | 3.2 | 3.1 | 2.9 | 4.2 | 2.0 | 3.0 | 3.0 | 3.2 |
| 11 | 1.5 | 1.5 | 3.0 | 2.8 | 1.4 | 2.1 | 2.1 | 2.0 |
| 13 | 1.2 | 2.0 | 3.4 | 3.2 | 2.3 | 2.9 | 4.3 | 1.5 |
| 110 | 6.0 | 4.6 | 2.8 | 5.3 | 8.1 | 4.4 | 4.3 | 1.8 |
| 130 | - | 2.0 | 2.3 | 4.9 | - | 1.7 | 3.7 | 1.7 |
| | CA | | | | MG | | | |
| 1 | 7 | 27 | 15 | 5 | 4.1 | 70 | 9.5 | 3.1 |
| 4 | 8 | 10 | 6 | 9 | 5.8 | 9.2 | 7.9 | 4.3 |
| 7 | 7 | 4 | 4 | 17 | 4.0 | 2.2 | 2.6 | 1.8 |
| 3 | 3 | 3 | 7 | 3 | 1.7 | 1.6 | 4.6 | 1.5 |
| 5 | 3 | 10 | 8 | 6 | 1.6 | 7.7 | 7.7 | 3.7 |
| 9 | 3 | 3 | 4 | 5 | 1.4 | 1.8 | 1.4 | 2.6 |
| 2 | 3 | 20 | 3 | 3 | 1.0 | 8.8 | 1.6 | 1.0 |
| 6 | 3 | 12 | 2 | 2 | 1.5 | 22 | 1.2 | 4.9 |
| 8 | 3 | 2 | 3 | 14 | 1.3 | 1.6 | 1.2 | 1.4 |
| 10 | 1.9 | 2.0 | 1.5 | 11 | 0.6 | 0.9 | 0.8 | 1.6 |
| 12 | 1.4 | 2.9 | 1.2 | 9 | 0.5 | 1.3 | 0.4 | - |
| 100 | 1.4 | 1.4 | 1.8 | 5 | 0.8 | 0.7 | 0.5 | 3.2 |
| 120 | - | 0.8 | 1.1 | 2 | - | 0.4 | 0.5 | 2.0 |
| 11 | 2.0 | 2.3 | 2.1 | 13 | 0.8 | 1.2 | 0.8 | 2.0 |
| 13 | 1.3 | 1.8 | 1.1 | 6 | 0.4 | 1.0 | 0.4 | 3.0 |
| 110 | - | 1.7 | 1.8 | 6 | - | 0.8 | 0.5 | 2.0 |
| 130 | - | 1.3 | 1.8 | 4 | - | 0.8 | 0.8 | 1.4 |

(Continued)

**TABLE E-8. (continued)**

| | Parameter Concentration, mg/l | | | | | |
|---|---|---|---|---|---|---|
| | Cu | | | Zn | | |
| Plot | 1975 | 1976 | 1977 | 1975 | 1976 | 1977 |
| 1 | 0.05 | 0.16 | 0.09 | 0.07 | 0.61 | 0.46 |
| 4 | 0.03 | 0.07 | 0.03 | 0.09 | 0.66 | 0.10 |
| 7 | 0.02 | 0.03 | 0.04 | 0.18 | 0.20 | 0.15 |
| 3 | 0.03 | 0.04 | 0.04 | 0.10 | 0.31 | 0.19 |
| 5 | 0.01 | 0.03 | - | 0.07 | 0.21 | 1.00 |
| 9 | 0.01 | 0.03 | 0.02 | 0.11 | 0.23 | 0.10 |
| 2 | 0.02 | 0.02 | 0.03 | 0.31 | 0.70 | - |
| 6 | 0.02 | 0.12 | 0.03 | 0.22 | 0.40 | 0.10 |
| 8 | 0.03 | 0.03 | 0.01 | 0.06 | 0.10 | - |
| 10 | 0.01 | 0.03 | 0.01 | 0.81 | 1.63 | 1.64 |
| 12 | 0.03 | 0.01 | 0.04 | 1.03 | 3.14 | 0.88 |
| 100 | 0.04 | 0.04 | 0.02 | 0.55 | 0.36 | 0.23 |
| 120 | 0.05 | 0.01 | 0.03 | 0.20 | 0.28 | 0.33 |
| 11 | 0.01 | 0.02 | 0.02 | 0.77 | 1.50 | 0.62 |
| 13 | 0.03 | 0.03 | 0.03 | 0.60 | 2.08 | 0.89 |
| 110 | - | 0.03 | 0.03 | - | 0.14 | 0.10 |
| 130 | 0.04 | 0.01 | 0.02 | 0.54 | 0.24 | 0.10 |

[*] Concentrations are volume-weighted means of monthly composite rain runoff samples. Not all months with runoff were included because of missing volume or concentration data. Extremely high values are likely due to runoff during or immediately after irrigation of lagoon effluent. Irrigation runoff was normally analyzed separately from rain runoff, but sampling or sample mixing errors evidently occurred.

[+] Irrigated plots: High - 1, 4, 7; Medium - 3, 5, 9; Low - 2, 6, 8. Pasture simulation plots: 10, 12, 100, 120. Hay simulation plots: 11, 13, 110, 130.

TABLE E-9. VOLUME-WEIGHTED CONCENTRATIONS IN RAIN RUNOFF FROM FERTILIZED PLOTS[δ]

| Year | Grazing | | Hay | | Grazing | | Hay | |
|---|---|---|---|---|---|---|---|---|
| | 10 | 12 | 11 | 13 | 100 | 120 | 110 | 130 |
| | TKN concentration, mg/l | | | | | | | |
| 1975 | 3.4 | 3.3 | 2.9 | 2.9 | -[#] | 2.8 | - | - |
| 1976 | 1.4 | 0.9 | 1.0 | 1.7 | 1.5 | 2.1 | 1.9 | 2.2 |
| 1977 | 2.2 | 2.4 | 2.0 | 2.1 | 2.2 | 2.6 | 3.2 | 2.3 |
| 1978[+] | 1.7 | 1.7 | 2.0 | 3.9 | 2.0 | 3.3 | 3.8 | 4.5 |
| | $NO_3$-N concentration, mg/l | | | | | | | |
| 1975 | 0.8 | 0.9 | 1.2 | 1.3 | - | 0.4 | - | - |
| 1976 | 0.6 | 0.7 | 0.4 | 0.7 | 0.3 | 0.1 | 0.3 | 0.7 |
| 1977 | 0.4 | 0.5 | 0.4 | 0.2 | 0.2 | 0.4 | 0.6 | 0.4 |
| 1978[+] | 0.7 | 0.7 | 1.6 | 0.8 | 0.6 | 1.4 | 2.4 | 1.8 |
| | Total N concentration (TKN + $NO_3$-N), mg/l | | | | | | | |
| 1975 | 4.2 | 4.2 | 4.1 | 4.2 | - | 3.2 | - | - |
| 1976 | 2.0 | 1.6 | 1.4 | 2.4 | 1.8 | 2.2 | 2.2 | 2.9 |
| 1977 | 2.6 | 2.9 | 2.4 | 2.3 | 2.4 | 3.0 | 3.8 | 2.7 |
| 1978[+] | 2.4 | 2.4 | 3.6 | 4.7 | 2.6 | 4.7 | 6.2 | 6.3 |
| | P concentration, mg/l | | | | | | | |
| 1975 | 0.3 | 0.3 | 0.4 | 0.2 | - | - | - | - |
| 1976 | 0.2 | 0.1 | 0.1 | 0.2 | 0.1 | 0.3 | 0.3 | 0.2 |
| 1977 | 0.2 | 0.2 | 0.2 | 0.2 | 0.4 | 0.4 | 0.4 | 0.3 |
| 1978 | 0.4 | 0.3 | 0.5 | 0.4 | 0.6 | 0.6 | 0.7 | 0.8 |
| | Cl concentration, mg/l | | | | | | | |
| 1975 | 1.9 | 2.1 | 3.6 | 1.3 | - | 0.9 | - | - |
| 1976 | 2.9 | 2.4 | 2.5 | 2.8 | 1.3 | 1.0 | 2.0 | 1.2 |
| 1977 | 1.6 | 2.0 | 2.9 | 1.5 | 1.5 | 1.9 | 1.6 | 2.1 |
| 1978 | 1.3 | 1.3 | 2.5 | 1.2 | 1.2 | 1.8 | 3.0 | 1.9 |
| | TOC concentration, mg/l | | | | | | | |
| 1976 | 13 | 6 | 13 | 7 | 15 | 24 | 21 | 8 |
| 1977 | 9 | 9 | 9 | 9 | 10 | 9 | 12 | 12 |
| 1978 | 9 | 8 | 9 | 8 | 11 | 11 | 16 | 12 |

[δ] Volume-weighted concentrations from Tables E-1, E-2, E-4, E-5, and E-6.

[+] All plots were topdressed with $NH_4NO_3$ on 7/6/78 and had high runoff concentrations in runoff on 7/11/78.

[#] No data (-).

# APPENDIX F

## ESTIMATED ANNUAL MASS TRANSPORT OF SELECTED CONSTITUENTS IN ALL TYPES OF SURFACE RUNOFF BY PLOT

EPA Form 2350-4 (4-80)

TYPING GUIDE SHEET

TABLE F-1. ESTIMATED TKN MASS IN ALL TYPES OF RUNOFF

| | | TKN mass in runoff, kg/ha[+] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | High | | | Medium | | | Low | | |
| Year | Type of runoff[‡] | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 |
| 1973 | R | 3.5 | 2.4 | 3.2 | 1.8 | 2.0 | 3.9 | 2.6 | 1.0 | 4.7 |
| | R + I | 1.0[#] | 0.0 | 1.0 | 0.1 | 0.0 | 0.2 | 0.0 | 0.0 | 0.5 |
| | I | - | - | - | - | - | - | - | 0.0 | - |
| | Total | 4.5 | 2.4 | 4.2 | 1.9 | 2.0 | 4.1 | 2.6 | 1.0 | 5.2 |
| 1974 | R | 10.4 | 10.3 | 18.6 | 1.9 | 1.6 | 20.9 | 4.9 | 0.6 | 6.9 |
| | R + I | 0.8 | - | 5.2 | 0.2 | 0.1 | 16.2[§] | 0.3 | 0.0 | 0.7 |
| | I | 5.4 | 58.8 | - | 0.8 | 0.0 | 0.0 | 1.3 | 0.0 | 0.1 |
| | Total | 16.6 | 69.1 | 23.8 | 2.9 | 1.7 | 37.1 | 6.5 | 0.6 | 7.7 |
| 1975 | R | 2.9[*] | 3.6[*] | 15.1[*] | 0.6[*] | 1.2[*] | 6.1[*] | 1.3[*] | 1.5[*] | 5.5[*] |
| | R + I | 2.7 | 7.0 | 0.0 | 0.0 | 2.8 | 0.5 | 0.0 | 0.0 | 0.0 |
| | I | 7.1 | 20.9[§] | - | 0.0 | 0.4 | 3.4 | 0.0 | 0.0 | 2.9[§] |
| | Total | 12.7 | 31.5 | 15.1 | 0.6 | 4.4 | 10.0 | 1.3 | 1.5 | 8.4 |
| 1976 | R | 0.0 | 0.0 | 2.7[*] | 0.0 | 0.0 | 1.6[*] | 0.1 | 0.0 | 1.9[*] |
| | R + I | 1.4 | 0.0 | 18.6 | 0.1 | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 |
| | I | 1.6 | 9.7 | 9.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.8 |
| | Total | 3.0 | 9.7 | 30.3 | 0.1 | 0.0 | 1.6 | 0.1 | 0.8 | 18.7 |
| 1977 | R | 0.0 | 1.1 | 4.8[*] | 0.0 | 1.1 | 3.8[*] | 0.0 | 0.2 | 3.6[*] |
| | R + I | 14.3 | 1.4 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| | I | 0.0 | 4.6 | 0.0 | 0.0 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 14.3 | 7.1 | 4.8 | 0.0 | 3.9 | 3.8 | 0.0 | 0.2 | 3.6 |
| 1978 | R | 1.7 | 0.1 | 8.4[*] | 0.3 | 0.1 | 4.0[*] | 0.2 | 0.2 | 4.3[*] |
| | R + I | 2.9 | 0.0 | 3.1[§] | 0.0 | 0.5 | 44.7[§] | 0.0 | 0.1 | 3.4[§] |
| | I | 0.0 | 0.0 | 0.2 | 0.0 | 1.7 | 0.1 | 0.0 | 0.3 | 0.4 |
| | Total | 4.6 | 0.1 | 11.7 | 0.3 | 2.3 | 48.8 | 0.2 | 0.6 | 8.1 |

[+] Mass calculated using total annual runoff and volume-weighted mean concentration of events that had concentration data (Tables Appendix E).

[‡] R-Rainfall, R+1 - Rainfall + irrigation mixed, I - Irrigation. Runoff events <0.05 cm for R and <0.01 cm for R+I and I were not included.

[#] No concentration data (-).

[§] Includes one or more events where collection barrel overflowed without any adjustment added for overflow.

[*] Includes one or more events where collection barrel overflowed and runoff total was adjusted (increased) using the SCS runoff curve number method.

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TABLE F-2. ESTIMATED $NO_3$-N MASS IN ALL TYPES OF RUNOFF

| Year | Type of runoff[≠] | $NO_3$-N mass in runoff, kg/ha[+] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | High | | | Medium | | | Low | | |
| | | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 |
| 1973 | R | 1.0 | 2.6 | 2.1 | 1.1 | 1.2 | 1.0 | 1.3 | 0.8 | 0.9 |
| | R + I | 0.2 | 0.0 | 0.2 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 |
| | I | -[#] | - | - | - | - | - | - | - | - |
| | Total | 1.2 | 2.6 | 2.3 | 1.2 | 1.2 | 1.0 | 1.3 | 0.8 | 1.0 |
| 1974 | R | 47.8 | 7.8 | 8.0 | 0.0 | 9.8 | 1.4 | 3.5 | 0.0 | 3.4 |
| | R + I | - | - | - | - | - | - | - | - | - |
| | I | - | - | - | - | - | - | - | - | - |
| | Total | 47.8 | 7.8 | 8.0 | 0.0 | 9.8 | 1.4 | 3.5 | 0.0 | 3.4 |
| 1975 | R | 1.6[*] | 5.4[*] | 10.4[*] | 0.3[*] | 0.5[*] | 4.6[*] | 0.5[*] | 0.7[*] | 3.4[*] |
| | R + I | 0.0 | 0.1 | 0.0 | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 |
| | I | - | - | - | 0.0 | - | - | 0.0 | 0.0 | - |
| | Total | 1.6 | 5.5 | 10.4 | 0.3 | 0.5 | 4.9 | 0.5 | 0.7 | 3.4 |
| 1976 | R | 0.0 | 0.0 | 2.2[*] | 0.0 | 0.0 | 1.8[*] | 0.1 | 0.0 | 1.4[*] |
| | R + I | 0.0 | 0.0 | - | 0.0 | 0.0 | 0.0 | 0.0 | - | 0.0 |
| | I | 0.0 | 0.0 | 0.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 0.0 | 0.0 | 2.5 | 0.0 | 0.0 | 1.8 | 0.1 | 0.0 | 1.4 |
| 1977 | R | 0.0 | 0.5 | 2.0[*] | 0.0 | 0.1 | 2.2[*] | 0.0 | 0.0 | 1.8[*] |
| | R + I | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | I | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 0.1 | 0.5 | 2.0 | 0.0 | 0.1 | 2.2 | 0.0 | 0.0 | 1.8 |
| 1978 | R | 1.3 | 0.1 | 6.4[*] | 0.2 | 0.1 | 3.8[*] | 0.2 | 0.0 | 3.8[*] |
| | R + I | 0.3 | 0.0 | 0.9[§] | 0.0 | 0.0 | 4.5[§] | 0.0 | 0.0 | 0.6[§] |
| | I | 0.0 | 0.0 | 0.1 | 0.0 | 0.0 | 0.1 | 0.0 | - | 0.2 |
| | Total | 1.6 | 0.1 | 7.4 | 0.2 | 0.1 | 8.4 | 0.2 | 0.0 | 4.6 |

+, ≠, #, §, * See footnotes to Table F-1.

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TABLE F-3. ESTIMATED TOTAL N IN ALL TYPES OF RUNOFF

| Year | Type of[≠] runoff | Total N mass in runoff, kg/ha[+] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | High | | | Medium | | | Low | | |
| | | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 |
| 1973 | R | 4.5 | 5.0 | 5.3 | 2.9 | 3.2 | 4.9 | 3.9 | 1.8 | 5.6 |
| | R + I | 1.2[#] | 0.0 | 1.2 | 0.2 | 0.0 | 0.2 | 0.0 | 0.0 | 0.6 |
| | I | - | - | - | - | - | - | - | 0.0 | - |
| | Total | 5.7 | 5.0 | 6.5 | 3.1 | 3.2 | 5.1 | 3.9 | 1.8 | 6.2 |
| 1974 | R | 58.2 | 18.1 | 26.6 | 1.9 | 11.4 | 22.3[§] | 8.4 | 0.6 | 10.3 |
| | R + I | 0.8 | - | 5.2 | 0.2 | 0.1 | 16.2 | 0.3 | 0.0 | 0.7 |
| | I | 5.4 | 58.8 | - | 0.8 | 0.0 | 0.0 | 1.3 | 0.0 | 0.1 |
| | Total | 64.4 | 76.9 | 31.8 | 2.9 | 11.5 | 38.5 | 10.0 | 0.6 | 11.1 |
| 1975 | R | 4.5[*] | 9.0[*] | 25.5[*] | 0.9[*] | 1.7[*] | 10.7[*] | 1.8[*] | 2.2[*] | 8.9[*] |
| | R + I | 2.7 | 7.0[§] | 0.0 | 0.0 | 2.8 | 0.8 | 0.0 | 0.0 | 0.0[§] |
| | I | 7.1 | 20.9 | - | 0.0 | 0.4 | 3.4 | 0.0 | 0.0 | 2.9 |
| | Total | 14.3 | 36.9 | 25.5 | 0.9 | 4.9 | 14.9 | 1.8 | 2.2 | 11.8 |
| 1976 | R | 0.0 | 0.0 | 4.9[*] | 0.0 | 0.0 | 3.4[*] | 0.2 | 0.0 | 3.3[*] |
| | R + I | 1.4 | 0.0 | 18.6 | 0.1 | 0.0 | 0.0 | 0.0 | 0.8 | 0.0 |
| | I | 1.6 | 9.7 | 9.3 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 16.8 |
| | Total | 3.0 | 9.7 | 32.8 | 0.1 | 0.0 | 3.4 | 0.2 | 0.8 | 20.1 |
| 1977 | R | 0.0 | 1.6 | 6.8[*] | 0.0 | 1.2 | 6.0[*] | 0.0 | 0.2 | 5.4[*] |
| | R + I | 14.4 | 1.4 | 0.0 | 0.0 | 0.6 | 0.0 | 0.0 | 0.0 | 0.0 |
| | I | 0.0 | 4.6 | 0.0 | 0.0 | 2.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 14.4 | 7.6 | 6.8 | 0.0 | 4.0 | 6.0 | 0.0 | 0.2 | 5.4 |
| 1978 | R | 3.0 | 0.2 | 14.8[*][§] | 0.5 | 0.2 | 7.8[*][§] | 0.4 | 0.2 | 8.1[*][§] |
| | R + I | 3.2 | 0.0 | 4.0 | 0.0 | 0.5 | 49.2 | 0.0 | 0.1 | 4.0 |
| | I | 0.0 | 0.0 | 0.3 | 0.0 | 1.7 | 0.2 | 0.0 | 0.3 | 0.6 |
| | Total | 6.2 | 0.2 | 19.1 | 0.5 | 2.4 | 57.2 | 0.4 | 0.6 | 12.7 |

+, ≠, #, §, * See footnotes to Table F-1.

TABLE F-4. ESTIMATED P MASS IN ALL TYPES OF RUNOFF

| Year | Type of runoff$^{≠}$ | P mass in runoff, kg/ha$^{+}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | High | | | Medium | | | Low | | |
| | | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 |
| 1973 | R | $3.7^{\#}$ | 2.8 | 4.0 | 1.1 | 0.8 | 1.7 | 0.9 | 0.2 | 1.5 |
| | R + I | - | - | - | - | 0.0 | - | - | 0.0 | - |
| | I | - | - | - | - | - | - | - | 0.0 | - |
| | Total | 3.7 | 2.8 | 4.0 | 1.1 | 0.8 | 1.7 | 0.9 | 0.2 | 1.5 |
| 1974 | R | 1.1 | 1.5 | 8.2 | 0.4 | 1.8 | 1.6 | 0.6 | 0.7 | 1.8 |
| | R + I | 0.8 | 2.2 | 2.6 | 0.2 | 0.2 | $0.7^{§}$ | 1.7 | 0.0 | 0.6 |
| | I | 3.3 | 17.7 | - | 0.0 | 0.0 | 0.0 | 1.0 | 0.0 | 0.0 |
| | Total | 5.2 | 21.4 | 10.8 | 0.6 | 2.0 | 2.3 | 3.3 | 0.7 | 2.4 |
| 1975 | R | $3.8^{*}$ | $6.4^{*}$ | $12.0^{*}$ | $0.8^{*}$ | $0.9^{*}$ | $2.0^{*}$ | $1.2^{*}$ | $1.0^{*}$ | $2.3^{*}$ |
| | R + I | 0.6 | - | 0.0 | 0.0 | 0.5 | - | 0.0 | 0.0 | 0.0 |
| | I | 1.8 | $6.8^{§}$ | - | 0.0 | - | 1.1 | 0.0 | 0.0 | $5.3^{§}$ |
| | Total | 6.2 | 13.2 | 12.0 | 0.8 | 1.4 | 3.1 | 1.2 | 1.0 | 7.6 |
| 1976 | R | 0.0 | 0.0 | $4.5^{*}$ | 0.0 | 0.0 | $1.4^{*}$ | 0.0 | 0.0 | $1.1^{*}$ |
| | R + I | 0.4 | 0.0 | 10.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 |
| | I | 0.5 | 2.1 | 2.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 5.0 |
| | Total | 0.9 | 2.1 | 17.6 | 0.0 | 0.0 | 1.4 | 0.0 | 0.4 | 6.1 |
| 1977 | R | 0.0 | 1.8 | $8.1^{*}$ | 0.0 | 0.6 | $6.8^{*}$ | 0.0 | 0.1 | $2.4^{*}$ |
| | R + I | 2.3 | 0.3 | 0.0 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 |
| | I | 0.0 | 0.9 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 2.3 | 3.0 | 8.1 | 0.0 | 1.2 | 6.8 | 0.0 | 0.1 | 2.4 |
| 1978 | R | 1.6 | 0.1 | $8.5^{*}$ | 0.4 | 0.1 | $2.5^{*}$ | 0.2 | 0.1 | $2.4^{*}$ |
| | R + I | 1.0 | 0.0 | $1.9^{§}$ | 0.0 | 0.1 | $14.6^{§}$ | 0.0 | 0.0 | $1.6^{§}$ |
| | I | 0.0 | 0.0 | 0.1 | 0.0 | 0.4 | 0.0 | 0.0 | 0.1 | 0.2 |
| | Total | 2.6 | 0.1 | 10.5 | 0.4 | 0.6 | 17.1 | 0.2 | 0.2 | 4.2 |

+, ≠, #, §, * See footnotes to Table F-1.

## TABLE F-5. ESTIMATED CL$^-$ MASS IN ALL TYPES OF RUNOFF

|  |  | Cl$^-$ mass in runoff, kg/ha[+] |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|
|  |  | High |  |  | Medium |  |  | Low |  |  |
| Year | Type of Runoff[‡] | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 |
| 1973 | R | 4.8[#] | 2.0 | 3.4 | 0.8 | 1.5 | 4.7 | 3.0 | 0.4 | 3.6 |
|  | R + I | 2.0 | 0.0 | 0.2 | 0.5 | 0.0 | --- | 0.3 | 0.0 | 0.1 |
|  | I | --- | --- | --- | --- | --- | --- | --- | 0.0 | --- |
|  | Total | 6.8 | 2.0 | 3.6 | 1.3 | 1.5 | 4.7 | 3.3 | 0.4 | 3.7 |
| 1974 | R | 10.3 | 11.6 | 30.5 | 3.6 | 9.9 | 29.1 | 7.4 | 4.9 | 18.4 |
|  | R + I | --- | --- | --- | --- | --- | --- | --- | 0.0 | --- |
|  | I | --- | 69.9 | 22.1 | --- | --- | 0.0 | --- | 0.0 | --- |
|  | Total | 10.3 | 81.5 | 52.6 | 3.6 | 9.9 | 29.1 | 7.4 | 4.9 | 18.4 |
| 1975 | R | 4.5[*] | 7.1[*] | 13.2[*] | 3.2[*] | 1.0[*] | 6.6[*] | 2.3[*] | 2.0[*] | 7.6[*] |
|  | R + I | 1.4 | 4.4 | 0.0 | 0.0 | 1.4 | 0.3 | 0.0 | 0.0 | 0.0 |
|  | I | --- | --- | --- | 0.0 | --- | --- | 0.0 | 0.0 | --- |
|  | Total | 5.9 | 11.5 | 13.2 | 3.2 | 2.4 | 6.9 | 2.3 | 2.0 | 7.6 |
| 1976 | R | 0.0 | 0.0 | 1.8[*] | 0.0 | 0.0 | 1.5[*] | 0.1 | 0.0 | 1.9[*] |
|  | R + I | 0.9 | 0.0 | 11.7 | 0.1 | 0.0 | 0.0 | 0.0 | 0.4 | 0.0 |
|  | I | 1.2 | 4.8 | 4.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 9.1 |
|  | Total | 2.1 | 4.8 | 18.1 | 0.1 | 0.0 | 1.5 | 0.1 | 0.4 | 11.0 |
| 1977 | R | 0.0 | 1.0 | 2.9[*] | 0.0 | 0.8 | 3.5[*] | 0.0 | 0.2 | 3.5[*] |
|  | R + I | 4.3 | 0.8 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.1 |
|  | I | 0.0 | 2.4 | 0.0 | 0.0 | 1.3 | 0.0 | 0.0 | 0.0 | 0.0 |
|  | Total | 4.3 | 4.2 | 2.9 | 0.0 | 2.5 | 3.5 | 0.0 | 0.2 | 3.6 |
| 1978 | R | 1.0 | 0.1 | 5.1[*] | 0.2 | 0.1 | 3.0[*] | 0.1 | 0.1 | 2.7[*] |
|  | R + I | 14.8 | 0.1 | 1.8[§] | 0.0 | 0.4 | 19.9[§] | 0.0 | 0.0 | 2.4[§] |
|  | I | 0.0 | 0.0 | 0.1 | 0.0 | 0.8 | 0.1 | 0.0 | 0.1 | 0.3 |
|  | Total | 15.8 | 0.2 | 7.0 | 0.2 | 1.3 | 23.0 | 0.1 | 0.2 | 5.4 |

+,‡,#,§,* See footnotes to Table F-1.

## TABLE F-6. ESTIMATED TOC MASS IN ALL TYPES OF RUNOFF

| Year | Type of Runoff[‡] | TOC mass in runoff, kg/ha[+] High 1 | High 4 | High 7 | Medium 3 | Medium 5 | Medium 9 | Low 2 | Low 6 | Low 8 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1973 | R | 15.4 | 7.1 | 11.8 | 4.1 | 4.9 | 9.4 | 12.0 | 2.7 | 9.6 |
| | R + I | 7.5 | 0.1 | 1.9 | 0.5 | 0.0 | 0.7 | 0.4 | 0.0 | 1.0 |
| | I | ---[#] | --- | --- | --- | --- | --- | --- | 0.0 | --- |
| | Total | 22.9 | 7.2 | 13.7 | 4.6 | 4.9 | 10.1 | 12.4 | 2.7 | 10.6 |
| 1974 | R | 18.2 | --- | 37.0 | --- | 10.1 | 31.7 | 21.2 | --- | 32.6 |
| | R + I | --- | --- | --- | --- | --- | --- | --- | 0.0 | --- |
| | I | --- | 122.6 | 30.2 | --- | --- | 0.0 | --- | 0.0 | 0.0 |
| | Total | 18.2 | 122.6 | 67.2 | --- | 10.1 | 31.7 | 21.2 | 0.0 | 32.6 |
| 1975 | R | --- | --- | 40.1[*] | --- | --- | --- | --- | --- | 32.6[*] |
| | R + I | --- | --- | 0.0 | 0.0 | --- | --- | 0.0 | 0.0 | 0.0 |
| | I | 15.0 | 55.5[§] | --- | 0.0 | 0.6 | --- | 0.0 | 0.0 | --- |
| | Total | 15.0 | 55.5 | 40.1 | 0.0 | 0.6 | --- | 0.0 | 0.0 | 32.6 |
| 1976 | R | 0.0 | 0.0 | 19.5[*] | 0.0 | 0.0 | 11.8[*] | 0.5 | 0.0 | 8.8[*] |
| | R + I | 2.6 | 0.0 | 24.2 | 0.2 | 0.0 | 0.1 | 0.0 | 0.7 | 0.0 |
| | I | 2.4 | 11.8 | 8.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 27.8 |
| | Total | 5.0 | 11.8 | 52.1 | 0.2 | 0.0 | 11.9 | 0.5 | 0.7 | 36.6 |
| 1977 | R | 0.1 | 2.7 | 18.1[*] | 0.0 | 1.4 | 18.1[*] | 0.0 | 1.1 | 15.9[*] |
| | R + I | 4.7 | 1.5 | 0.0 | 0.0 | 0.8 | 0.0 | 0.0 | 0.0 | 0.1 |
| | I | 0.0 | 2.9 | 0.0 | 0.0 | 1.9 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 4.8 | 7.1 | 18.1 | 0.0 | 4.1 | 18.1 | 0.0 | 1.1 | 16.0 |
| 1978 | R | 5.0 | 0.4 | 30.9[*] | 1.8 | 1.8 | 19.7[*] | 1.2 | 0.3 | 23.9[*] |
| | R + I | 2.2 | 0.2 | 5.2[§] | 0.0 | 0.3 | 19.9[§] | 0.1 | 0.1 | 6.0[§] |
| | I | 0.0 | 0.0 | 0.5 | 0.0 | 0.6 | 0.2 | 0.0 | 0.4 | 1.1 |
| | Total | 7.2 | 0.6 | 36.6 | 1.8 | 2.7 | 39.8 | 1.3 | 0.8 | 31.0 |

+,‡,#,§,* See footnotes to Table F-1.

## TABLE F-7. ESTIMATED ANNUAL AMOUNTS OF K IN ALL TYPES OF RUNOFF

| | | K mass in runoff, kg/ha[+] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | High | | | Medium | | | Low | | |
| Year | Type of Runoff[≠] | 1 | 4 | 7 | 3 | 5 | 9 | 2 | 6 | 8 |
| 1973 | R | 11.2 | 9.0 | 8.4 | 3.6 | 5.2 | 13.6 | 9.3 | 1.5 | 7.2 |
| | R+I | 4.1[#] | 0.0 | 1.6 | 0.1 | 0.0 | 0.5 | 0.2 | 0.0 | 0.6 |
| | I | - | - | - | - | - | - | - | - | - |
| | Total | 15.3 | 9.0 | 10.0 | 3.7 | 5.2 | 14.1 | 9.5 | 1.5 | 7.8 |
| 1974 | R | 15.1 | 20.8 | 56.8 | 6.2 | 12.4 | 40.2 | 11.7 | 4.4 | 26.0 |
| | R+I | - | - | - | - | - | - | - | - | - |
| | I | - | 84.7 | 24.3 | - | - | 0.0 | - | 0.0 | - |
| | Total | 15.1 | 105.5 | 81.1 | 6.2 | 12.4 | 40.2 | 11.7 | 4.4 | 26.0 |
| 1975 | R | 6.2[*] | 9.7[*] | 19.2[*] | 1.9[*] | 2.9[*] | 8.1[*] | 1.7[*] | 2.0[*] | 9.3[*] |
| | R+I | 1.9 | - | 0.0 | 0.0 | 2.3 | - | 0.0 | 0.0 | 0.0 |
| | I | 5.9 | 16.1[§] | 0.1 | 0.0 | 0.3 | 2.7 | 2.7 | 0.0 | 9.4[§] |
| | Total | 14.0 | 25.8 | 19.3 | 1.9 | 5.5 | 10.8 | 1.7 | 2.0 | 18.7 |
| 1976 | R | 0.0 | 0.0 | 11.1[*] | 0.0 | 0.0 | 7.5[*] | 0.3 | 0.0 | 7.1[*] |
| | R+I | 1.1 | 0.0 | 12.7 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | I | 1.8 | 3.1 | 8.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 13.9 |
| | Total | 2.9 | 3.1 | 31.9 | 0.0 | 0.0 | 7.5 | 0.3 | 0.0 | 21.0 |
| 1977 | R | 0.3 | 1.1 | 7.2[*] | 0.0 | 0.7 | 4.5[*] | 0.0 | 0.9 | 7.6[*] |
| | R+I | 9.2 | 1.4 | 0.0 | 0.0 | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 |
| | I | 0.0 | 4.2 | 0.0 | 0.0 | 2.3 | 0.0 | 0.0 | 0.0 | 0.0 |
| | Total | 9.5 | 6.7 | 7.2 | 0.0 | 3.4 | 4.5 | 0.0 | 0.9 | 7.6 |
| 1978 | R | 1.0 | 0.2 | 2.4[*] | 0.5 | 0.1[*] | 8.0 | 0.1 | 0.2 | 1.7[*] |
| | R+I | 1.2 | 0.0 | - | 0.0 | 0.1 | 9.8[§] | 0.0 | 0.0 | 0.2[§] |
| | I | 0.0 | 0.0 | 0.0 | 0.0 | 1.5 | 0.0 | 0.0 | 0.2 | 0.0 |
| | Total | 2.2 | 0.2 | 2.4 | 0.5 | 1.7 | 17.8 | 0.1 | 0.4 | 1.9 |

+, ≠, #, §, * (See footnotes to Table F-1).

TABLE F-8. ESTIMATED MASS IN RUNOFF FROM FERTILIZED PLOTS

| Year | Grazing | | Hay | | Grazing | | Hay | |
|---|---|---|---|---|---|---|---|---|
| | 10 | 12 | 11 | 13 | 100 | 120 | 110 | 130 |
| | **TKN mass, kg/ha[+]** | | | | | | | |
| 1975[*] | 4.5 | 4.5 | 3.9 | 3.5 | -[#] | - | - | - |
| 1976 | 0.5 | 0.2 | 0.3 | 0.3 | 0.6 | 0.3 | 0.5 | 0.3 |
| 1977 | 1.8 | 1.2 | 1.4 | 1.0 | 1.9 | 1.7 | 1.3 | 0.7 |
| 1978[*] | 2.2 | 1.6 | 2.2 | 3.6 | 3.1 | 2.9 | 3.3 | 2.5 |
| | **$NO_3$-N mass, kg/ha[+]** | | | | | | | |
| 1975[*] | 1.1 | 1.2 | 1.6 | 1.6 | -[#] | - | - | - |
| 1976 | 0.2 | 0.2 | 0.1 | 0.1 | 0.1 | 0.0 | 0.1 | 0.1 |
| 1977 | 0.3 | 0.2 | 0.3 | 0.1 | 0.2 | 0.3 | 0.2 | 0.1 |
| 1978[*] | 0.9 | 0.6 | 1.7 | 0.7 | 0.9 | 1.2 | 2.1 | 1.0 |
| | **Total N mass (TKN + $NO_3$-N), kg/ha[+]** | | | | | | | |
| 1975[*] | 5.6 | 5.7 | 5.5 | 5.1 | -[#] | - | - | - |
| 1976 | 0.7 | 0.4 | 0.4 | 0.4 | 0.7 | 0.3 | 0.6 | 0.4 |
| 1977 | 2.1 | 1.4 | 1.7 | 1.1 | 2.1 | 2.0 | 1.5 | 0.8 |
| 1978[*] | 3.1 | 2.2 | 3.9 | 4.3 | 4.0 | 4.1 | 5.4 | 3.5 |
| | **P mass, kg/ha[+]** | | | | | | | |
| 1975[*] | 0.4 | 0.4 | 0.5 | 0.3 | -[#] | - | - | - |
| 1976 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.0 |
| 1977 | 0.2 | 0.1 | 0.1 | 0.1 | 0.4 | 0.3 | 0.2 | 0.1 |
| 1978[*] | 0.5 | 0.3 | 0.5 | 0.4 | 0.9 | 0.5 | 0.6 | 0.4 |
| | **$Cl^-$ mass, kg/ha[+]** | | | | | | | |
| 1975[*] | 2.5 | 2.8 | 4.9 | 1.6 | -[#] | - | - | - |
| 1976 | 1.0 | 0.6 | 0.6 | 0.5 | 0.5 | 0.1 | 0.6 | 0.2 |
| 1977 | 1.3 | 1.0 | 2.0 | 0.8 | 1.3 | 1.2 | 0.6 | 0.6 |
| 1978[*] | 1.7 | 1.2 | 2.7 | 1.1 | 1.8 | 1.6 | 2.6 | 1.1 |
| | **TOC mass, kg/ha[+]** | | | | | | | |
| 1976 | 4.8 | 1.5 | 3.4 | 1.4 | 6.4 | 2.9 | 6.1 | 1.3 |
| 1977 | 7.4 | 4.3 | 6.4 | 4.4 | 8.9 | 5.8 | 5.0 | 3.8 |
| 1978[*] | 11.9 | 7.1 | 10.1 | 7.1 | 17.2 | 9.3 | 14.2 | 6.7 |

[+] Mass calculated using total annual runoff and volume-weighted mean concentration of events that had concentration data (Table E-9).

[*] All plots had event(s) where collection barrel overflowed and runoff was adjusted (increased) using the SCS runoff curve number method.

[#] No data (-).

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